BAE SYSTEMS

MULTIPATHWAY RISK ASSESSMENT REPORT FOR THE ENERGETIC WASTE INCINERATORS

RADFORD ARMY AMMUNITION PLANT

RADFORD, VIRGINIA

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AAPC	Alliant Ammunition and Powder Company
ABS	absorption factor
ADD	average daily dose
ADI	average daily intake
AEGL	acute exposure guideline level
AERMOD	AMS/EPA Regulatory Model
AHQ	acute hazard quotient
AIEC	acute inhalation exposure criteria
ALM	Adult Lead Exposure Model
AP-42	Compilation of Air Pollutant Emission Factors
APC	air pollution control
BAE	BAE Systems, Ordnance Systems, Inc.
BCF	bioconcentration factor
BMF	biomagnification factor
BPIP	Building Profile Input Program
BTAG	Biological Technical Assistance Group
BW	body weight
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CO	carbon monoxide
CO_2	carbon dioxide
COPC	constituent of potential concern
CSF	cancer slope factor
DOD	Department of Defense
DOE	Department of Energy
ECO-SSL	ecological soil screening level
ECOTOX	Ecotoxicology Knowledgebase
ERPG	emergency response planning guideline
ESQ	ecological screening quotient
EWI	energetic waste incinerator
FCM	food chain multiplier

GAQM	Guidelines on Air Quality Models
GEP	good engineering practice
HHRA	human health risk assessment
HHRAP	Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities
HI	hazard index
HQ	hazard quotient
HWC NESHAP	Hazardous Waste Combustor National Emission Standards for Hazardous Air Pollutants
IEUBK	Integrated Exposure Uptake Biokinetic
LADD	lifetime average daily dose
LOAEL	lowest observable effect level
MACT	maximum achievable control technology
MDL	method detection limit
MER	measured emission rate
MPRA	multipathway risk assessment
NAAQS	National Ambient Air Quality Standards
NED	National Elevation Dataset
NEW	net explosive weight
NO	nitrogen oxide
NOx	nitrogen oxides
NOAA	National Oceanic and Atmospheric Association
NOAEL	no observable effect level
NRHEEC	National Report on Human Exposures to Environmental Chemicals
ORNL	Oak Ridge National Laboratories
PAC	protective action criteria
PAH	polynuclear aromatic hydrocarbon
PCDD	polychlorinated dibenzo-p-dioxin
PCDF	polychlorinated dibenzofuran
PIC	product of incomplete combustion
PM	particulate matter
PUF	process upset factor
RB	risk burn
RCRA	Resource Conservation and Recovery Act
RFAAP	Radford Army Ammunition Plant
RfC	reference concentration

RfD	reference dose
RME	reasonable maximum exposure
RSL	regional screening level
SLERA	screening level ecological risk assessment
SLERAP	Screening-Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities
SO_2	sulfur dioxide
SQuiRTs	Screening Quick Reference Tables
TCDD	Tetrachlorodibenzo(p)dioxin
TEEL	temporary emergency exposure limit
TEF	toxicity equivalent factor
TEQ	toxic equivalent
TestAmerica	TestAmerica Laboratories, Inc.
TRV	toxicity reference value
UF	uncertainty factor
U.S.C.	United States Code
USCB	United States Census Bureau
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTM	Universal Transverse Mercator coordinate system
VDEQ	Virginia Department of Environmental Quality
VDGIF	Virginia Department of Game and Inland Fisheries
VOC	volatile organic compounds
WEFH	Wildlife Exposure Factors Handbook

1.0 INTRODUCTION

This multipathway risk assessment (MPRA) report is being submitted by BAE Systems, Ordnance Systems, Inc., (BAE) to fulfill a requirement of the Resource Conservation and Recovery Act (RCRA) permit application for the energetic waste incinerators (EWIs) operated at the Radford Army Ammunition Plant (RFAAP). This report documents the methodologies by which BAE evaluated the risks to human health and the environment resulting from continued operation of the EWIs.

This MPRA was required by the Virginia Department of Environmental Quality (VDEQ) under the authority of the RCRA Omnibus provision granted by Title 40 Code of Federal Regulations (CFR) Part 270.32(b)(2). While a prior MPRA was performed for the EWIs at the RFAAP, VDEQ requested that a new assessment be performed due to changes in modeling guidance, meteorological data availability, and toxicity data.

1.1 BACKGROUND

Although there are no specific promulgated requirements for MPRAs in RCRA, previous permitting efforts in Virginia and throughout the United States have included this requirement as part of the permitting process for hazardous waste combustors. This policy was initiated by the United States Environmental Protection Agency (USEPA) as part of the Hazardous Waste Minimization and Combustion Strategy. Site-specific MPRAs were performed as part of the RCRA permitting process for many hazardous waste thermal treatment units to ensure protection of human health and the environment. Specifically, these site-specific MPRAs are intended to address potential concerns about hazardous constituents that may be found in unit emissions, including dioxins, furans, metals, and non-dioxin products of incomplete combustion (PICs). As such, an MPRA was performed for the EWIs as part of the application for the current RCRA permit and was required as a condition of the renewal of that permit.

The “omnibus” authority of Section 3005(c)(3) of RCRA, 42 United States Code (U.S.C.) 6925(c)(3), and 40 CFR § 270.32(b)(2) gives the Agency both the authority and the responsibility to establish permit conditions on a case-by-case basis as necessary to protect human health and the environment. Performance of a site-specific MPRA can provide the information necessary to determine what, if any, additional permit conditions are necessary to ensure that operation of the EWIs is protective of human health and the environment. Under 40 CFR § 270.10(k), the Agency may require a permit applicant to submit additional information (*e.g.*, a site-specific MPRA) that is needed to establish permit conditions under the omnibus authority. The VDEQ requested that RFAAP perform this MPRA as part of the RCRA permit renewal for the EWIs.

1.2 PURPOSE AND SCOPE

BAE is submitting this MPRA report in conjunction with the renewal application for the EWIs' RCRA permit. The MPRA was conducted in accordance with the methods described in USEPA's guidance document entitled, *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP) (USEPA, 2005) and *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (SLERAP) (USEPA, 1999b). In addition, the approved MPRA protocol for RFAAP's open burning grounds, entitled *Multipathway Risk Assessment Protocol for the Radford Army Ammunition Plant Open Burning Grounds* (RFAAP, 2019b), was used as a guide for conducting the EWI MPRA. The MPRA was site-specific with respect to the source and dispersion of emissions and the locations of potential receptors. Default variable values were used to represent the potential intake of the hypothetical receptors located throughout the surrounding community.

This MPRA report presents the following information:

- Constituents of potential concern (COPC) evaluated in the MPRA and the emission factors used for them;
- Site-specific exposure pathways and hypothetical receptors evaluated in the human health risk assessment (HHRA);
- Procedures used in the estimation of human health risk associated with potential direct and indirect exposures to EWI emissions;
- Calculated risk and hazard estimates for each human health exposure scenario;
- Community and food-web ecological receptors evaluated in the screening-level ecological risk assessment (SLERA);
- Calculated risk estimates for the community and food-web ecological receptors; and
- As appropriate, recommendation of site-specific risk-based limitations for the OBG to ensure protection of human health in the surrounding community.

The goal of the MPRA described by this document was to demonstrate that emissions from the EWIs meet the site-specific risk-based goals established by the VDEQ and determined by them to be sufficiently protective of the surrounding human health and the environment.

1.3 FACILITY CHARACTERIZATION

BAE operates a munitions propellant manufacturing facility at the RFAAP in Radford, Virginia. The primary mission of the RFAAP is to supply solvent and solventless propellant and explosives to the United States Armed Forces. The RFAAP is a government-owned, contractor operated, military industrial installation under the jurisdiction of the United States Army. Manufacturing operations at the RFAAP commenced in 1941 and have been in continuous operation ever since. Currently, the RFAAP is recognized as the largest supplier of ammunition propellant to the United States Department of Defense (DOD) and as a major producer of medium caliber ammunition and commercial and military smokeless powder.

1.3.1 SURROUNDING AREA

The RFAAP is situated in hilly terrain in Pulaski and Montgomery Counties in southwest Virginia and is divided into two sections: the main plant, and the Horseshoe Area. The New River separates the two counties and these two portions of the facility. The EWIs are located in the middle northern portion of the Horseshoe Area, as shown on Figure 1-1. Surrounding land use is primarily a combination of deciduous forest and pastureland, intermingled with small residential areas. The main developed areas are Blacksburg to the northwest, Christiansburg to the east, and Radford to the southwest. The location of these towns relative to the RFAAP is demonstrated on Figure 1-2.

With hilly terrain and numerous drainage areas, the area surrounding the RFAAP provides multiple streams and creeks for fishing. In addition, the New River itself, serves as a major resource for fishing, supporting populations of nearly every major freshwater game fish in the state, including: smallmouth bass, spotted bass, largemouth bass, rock bass, striped bass, white bass, hybrid striped bass, muskellunge, walleye, black crappie, channel catfish, flathead catfish, yellow perch, redbreast sunfish, and bluegill (VDGIF, 2018). In addition, the New River is utilized as a drinking water supply for nearby communities.

1.3.2 ENERGETIC WASTE INCINERATORS

Various types of hazardous waste are generated as part of the RFAAP production operations. These wastes are managed via one of three mechanisms. The hazardous energetic wastes are treated onsite in either the hazardous waste incinerators or the open burning grounds. Non-energetic hazardous wastes are generally sent offsite for disposal.

The incinerator complex at RFAAP consists of two identical EWIs, referred to as Incinerators 440 and 441. These two units are identical in every aspect of their design and operations. All components, materials, and proportions are the same. Each unit consists of a rotary kiln incinerator and secondary combustion chamber, an evaporative cooler, and an air pollution control (APC) system, which includes a fabric filter baghouse, a precooler/quench, and a packed bed scrubber. Emissions from each incinerator are exhausted to the atmosphere through separate 35-foot tall exhaust stacks. The incinerators and Grinder Building may be in operation 24 hours per day, 365 days per year. Downtime occurs due to changes in production demands, scheduled maintenance periods, or unscheduled maintenance activities relating to mechanical difficulties. The two units operate independent of the other. Both units may operate at the same time if waste disposal needs demand it, but, generally, only one unit is operated at a time.

The two EWIs were designed to incinerate off specification or production waste energetic mixtures. These wastes are brought from the production area to the Grinder Building, where they are ground and mixed with water to form a slurry. A pump system located in the Grinder Building supplies both incinerators with this slurry feed on a continuous basis. The composition of the energetic waste mixtures generated and fed to the incinerators varies due to changes in the production schedule. The wastes are hazardous due to their ignitability, reactivity, and/or toxicity for certain metals and organics.

FIGURE 1-1
LOCATION OF THE EWIS

FIGURE 1-2
LOCATION OF RFAAP

2.0 COMPOUNDS OF POTENTIAL CONCERN

The COPCs for this risk assessment were based largely on those COPCs identified in the prior MPRA for the EWIs. Slight modifications were made based on changes in laboratory detection limits or the availability of toxicity data. This section provides an overview of that process and documents the final COPCs included in the risk assessment and the emission factors utilized for them.

2.1 COPC SELECTION

COPCs for the prior MPRA were identified based on their potential to pose increased risk or hazard via one or more of the exposure pathways. This identification process focused on compounds that:

- are likely to be emitted, based on the presence of the compound or its precursors in the waste feed and emissions;
- are potentially toxic to humans; and/or
- have a propensity for bioaccumulating or bioconcentrating in food chains.

A detailed discussion of that selection process can be found in the Alliant Ammunition and Powder Company (AAPC) *Risk Assessment Protocol* submitted in January 2001 (AAPC, 2001a). In brief, the following criteria were applied:

- Key target groups of compounds were identified based on waste analysis data and typical emissions reported from hazardous waste combustors as documented in the HHRAP. These included: dioxins and furans, polynuclear aromatic hydrocarbons, nitroaromatics, phthalates, other organic compounds, and metals.
- Individual compounds within each group were selected based on HHRAP recommendations, waste analytical data, USEPA recommendations in other risk assessment guidance (*e.g.,* USEPA, 1993), and combustion chemistry.

This selection process resulted in a total of 87 COPCs that were identified for the prior MPRA as specified in AAPC *Human Health Risk Assessment Report* submitted in June 2001 (AAPC, 2001b). Of these, 75 were found in at least one run of stack emissions testing during a June 2000 risk burn and that had adequate fate, transport, and toxicological data to be quantitatively evaluated.

The COPC list from the prior MPRA was modified for this MPRA based on the following criteria developed in conjunction with VDEQ during negotiations on the notices of deficiencies (NODs) issued on the RCRA permit application (VDEQ, 2016):

- All COPCs detected in the June 2000 risk burn were included in this MPRA.
- All of the 17 dioxin/furan congeners discussed in the HHRAP were included in this MPRA regardless of whether they were detected in the June 2000 risk burn. Emission rates for the MPRA were modeled at either the measured emission rate or the method detection limit (MDL) from the June 2000 test.

- Three metals (magnesium, potassium, and sodium) that were reported as non-detect in the June 2000 risk burn but that have the potential to be in RFAAP wastes were included in the MPRA. Emission rates for magnesium and potassium were modeled at the June 2000 MDL and sodium was modeled at 1/2 of the June 2000 MDL.
- Two metals (aluminum and copper) that were excluded from the prior risk assessment due to a lack of fate, transport, or toxicity data that now had such data available were included as COPCs for this MPRA at the emission rates measured during the June 2000 test.
- Three metals (iron, phosphorous, and tin) that were excluded from the prior risk assessment due to a lack of laboratory capability in June 2000 and for which TestAmerica Laboratories, Inc., in Knoxville, Tennessee, (TestAmerica) now has analytical capability were included in the MPRA. Emission rates for phosphorous and time were modeled at the current laboratory MDL and the emission rate for iron was modeled at ½ of the current laboratory MDL.
- Any of the 18 specific energetic compounds discussed by VDEQ in their July 2016, letter on the RCRA permit NODs that are used in RFAAP formulations or that could be produced from RFAAP formulations and for which TestAmerica has current measurement capability were included in the MPRA at the current laboratory MDL.
- Volatile or semivolatile organics or nitroaromatics for which the laboratory did not have analytical capability in June 2000 but for which TestAmerica has current measurement capability were included in the MPRA at the current laboratory MDL.

After these modifications, the final COPC list for this MPRA was determined and is provided in Table 2-1. Which the exception of eight compounds, each one of the selected COPCs were included in the HHRA; however, certain COPCs were excluded from the SLERA due to a lack of ecological assessment data. Those compounds excluded from the HHRA were excluded because they do not have available fate, transport, or toxicity data for the HHRA. The impact of excluding these compounds from the quantitative HHRA and SLERA is discussed in Section 9, Uncertainty.

TABLE 2-1
COPCS EVALUATED IN THE MPRA [1]

COPC	HHRA?	SLERA?
Dioxins and Furans		
1,2,3,4,5,7,8,9-Octachlorodibenzo(p)dioxin	Yes	Yes
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	Yes	Yes
1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin	Yes	Yes
1,2,3,4,6,7,8-Heptachlorodibenzofuran	Yes	Yes
1,2,3,4,7,8,9-Heptachlorodibenzofuran	Yes	Yes
1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin	Yes	Yes
1,2,3,4,7,8-Hexachlorodibenzofuran	Yes	Yes
1,2,3,6,7,8-Hexachlorodibenzo(p)dioxin	Yes	Yes
1,2,3,6,7,8-Hexachlorodibenzofuran	Yes	Yes

TABLE 2-1 (CONTINUED)
COPCS EVALUATED IN THE MPRA [1]

COPC	HHRA?	SLERA?
Dioxins and Furans (continued)		
1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin	Yes	Yes
1,2,3,7,8,9-Hexachlorodibenzofuran	Yes	Yes
1,2,3,7,8-Pentachlorodibenzo(p)dioxin	Yes	Yes
1,2,3,7,8-Pentachlorodibenzofuran	Yes	Yes
2,3,4,6,7,8-Hexachlorodibenzofuran	Yes	Yes
2,3,4,7,8-Pentachlorodibenzofuran	Yes	Yes
2,3,7,8-Tetrachlorodibenzo(p)dioxin	Yes	Yes
2,3,7,8-Tetrachlorodibenzofuran	Yes	Yes
Nitroaromatics and Energetics		
2,4-Dinitrotoluene	Yes	Yes
2-Nitrotoluene	Yes	No
3-Nitrotoluene	Yes	Yes
4-Nitrotoluene	Yes	Yes
HMX	Yes	Yes
Nitroglycerin	Yes	Yes
RDX	Yes	Yes
Phthalates		
bis(2-ethylhexyl)phthalate	Yes	Yes
Butylbenzyl phthalate	Yes	Yes
Diethyl phthalate	Yes	Yes
Other Semivolatile and Volatile Organics		
2,4,5-Trichlorophenol	Yes	No
Aniline	Yes	Yes
Benzoic acid	Yes	Yes
Benzyl alcohol	Yes	Yes
Naphthalene	Yes	Yes
Pentachloronitrobenzene	Yes	No
Pentachlorophenol	Yes	Yes
Phenol	Yes	Yes
1,1-Dichloropropene	No	No
1,2,3-Trichlorobenzene	Yes	Yes
1,2-Dibromo-3-Chloropropane	Yes	No
1,3-Dichloropropane	Yes	No
2,2-Dichloropropane	No	No

TABLE 2-1 (CONTINUED)
COPCS EVALUATED IN THE MPRA [1]

COPC	HHRA?	SLERA?
2-Chlorotoluene	No	No
2-Hexanone	Yes	Yes
4-Chlorotoluene	No	No
4-Isopropyltoluene	No	No
Acetone	Yes	Yes
Bromochloromethane	Yes	No
Isopropylbenzene	Yes	Yes
Methylene chloride	Yes	Yes
n-Butylbenzene	Yes	No
N-Propylbenzene	Yes	Yes
Styrene	Yes	Yes
tert-Butylbenzene	Yes	No
Toluene	Yes	Yes
Metals		
Aluminum	Yes	Yes
Antimony	Yes	Yes
Cadmium	Yes	Yes
Chromium (as hexavalent)	Yes	Yes
Copper	Yes	Yes
Iron	Yes	Yes
Lead	Yes	No
Magnesium	No	No
Mercury	Yes	No
Mercuric chloride	Yes	No
Nickel	Yes	Yes
Phosphorous	Yes	Yes
Potassium	No	No
Sodium	No	No
Tin	Yes	Yes
Zinc	Yes	Yes

[1] Those compounds for which "No" is specified under the second or third column (HHRA or SLERA) did not have adequate fate, transport, and/or toxicity data to conduct the specified evaluation. The impact of these compounds being excluded from the quantitative assessment is discussed in Section 9, Uncertainty.

2.2 COPC Emission Rates

The emission rates for each COPC were determined from either the site-specific emissions testing conducted for the prior MPRA's risk burn in June 2000 or from laboratory MDLs and emission characteristics from the June 2000 risk burn. Copies of the laboratory and emissions data from the June 2000 risk burn are documented in the AAPC *Trial Burn Report* dated January 2001 (AAPC, 2001c). Direction on the use of the MDL or ½ of the MDL for those based on current laboratory method capability was provided by VDEQ in NODs issued on the RCRA permit application.

Table 2-2
COPC Emission Rates for the MPRA

COPC	Emission Rate (g/s)	Basis [1, 2]
Dioxins and Furans [3]		
1,2,3,4,5,7,8,9-Octachlorodibenzo(p)dioxin	4.89E-16	June 2000 RB MDL
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	9.78E-15	June 2000 MER * PUF
1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin	2.09E-13	June 2000 MER * PUF
1,2,3,4,6,7,8-Heptachlorodibenzofuran	6.67E-13	June 2000 MER * PUF
1,2,3,4,7,8,9-Heptachlorodibenzofuran	8.22E-14	June 2000 MER * PUF
1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin	2.58E-13	June 2000 RB MDL
1,2,3,4,7,8-Hexachlorodibenzofuran	3.49E-12	June 2000 MER * PUF
1,2,3,6,7,8-Hexachlorodibenzo(p)dioxin	4.41E-13	June 2000 MER * PUF
1,2,3,6,7,8-Hexachlorodibenzofuran	7.04E-13	June 2000 MER * PUF
1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin	7.55E-13	June 2000 MER * PUF
1,2,3,7,8,9-Hexachlorodibenzofuran	1.76E-13	June 2000 RB MDL
1,2,3,7,8-Pentachlorodibenzo(p)dioxin	3.25E-12	June 2000 MER * PUF
1,2,3,7,8-Pentachlorodibenzofuran	2.16E-13	June 2000 MER * PUF
2,3,4,6,7,8-Hexachlorodibenzofuran	3.73E-12	June 2000 MER * PUF
2,3,4,7,8-Pentachlorodibenzofuran	4.80E-12	June 2000 MER * PUF
2,3,7,8-Tetrachlorodibenzo(p)dioxin	2.27E-12	June 2000 RB MDL
2,3,7,8-Tetrachlorodibenzofuran	2.34E-12	June 2000 MER * PUF
Nitroaromatics and Energetics		
2,4-Dinitrotoluene	6.60E-07	June 2000 MDL
2-Nitrotoluene	1.10E-06	September 2020 MDL
3-Nitrotoluene	1.59E-06	September 2020 MDL
4-Nitrotoluene	1.59E-06	September 2020 MDL
HMX	3.89E-06	September 2020 MDL
Nitroglycerin	4.00E-05	September 2020 MDL
RDX	7.22E-07	September 2020 MDL

TABLE 2-2 (CONTINUED)
COPC EMISSION RATES FOR THE MPRA

COPC	EMISSION RATE (G/S)	BASIS [1,2]
Phthalates		
bis(2-ethylhexyl)phthalate	1.15E-05	June 2000 MER * PUF
Butylbenzyl phthalate	9.03E-06	June 2000 MER * PUF
Diethyl phthalate	2.34E-06	June 2000 MER * PUF
Other Semivolatile and Volatile Organics		
2,4,5-Trichlorophenol	2.74E-06	September 2020 MDL
Aniline	4.67E-06	September 2020 MDL
Benzoic acid	5.96E-04	June 2000 MER * PUF
Benzyl alcohol	1.95E-04	June 2000 MER * PUF
Naphthalene	5.07E-07	June 2000 MER * PUF
Pentachloronitrobenzene	4.84E-06	September 2020 MDL
Pentachlorophenol	1.65E-05	September 2020 MDL
Phenol	1.45E-05	June 2000 MER * PUF
1,2,3-Trichlorobenzene	1.87E-06	September 2020 MDL
1,2-Dibromo-3-Chloropropane	1.06E-06	September 2020 MDL
1,3-Dichloropropane	2.71E-07	September 2020 MDL
2-Hexanone	3.11E-06	September 2020 MDL
Acetone	3.00E-04	June 2000 MER * PUF
Bromochloromethane	7.32E-07	September 2020 MDL
Isopropylbenzene	3.32E-07	September 2020 MDL
Methylene chloride	1.65E-04	June 2000 MER * PUF
n-Butylbenzene	6.21E-07	September 2020 MDL
N-Propylbenzene	4.81E-07	September 2020 MDL
Styrene	5.34E-07	September 2020 MDL
tert-Butylbenzene	5.09E-07	September 2020 MDL
Toluene	1.92E-04	June 2000 MER * PUF
Metals		
Aluminum	4.50E-05	June 2000 MER * PUF
Antimony	1.84E-06	June 2000 MER * PUF
Cadmium	4.32E-07	June 2000 MER * PUF
Chromium (as hexavalent)	4.59E-06	June 2000 MER * PUF
Copper	1.00E-04	June 2000 MER * PUF
Iron	3.60E-06	½ of September 2020 MDL

TABLE 2-2 (CONTINUED)
COPC EMISSION RATES FOR THE MPRA

COPC	EMISSION RATE (G/S)	BASIS [1,2]
Metals (continued)		
Lead	6.73E-04	June 2000 MER * PUF
Mercury	1.44E-07	June 2000 MER * PUF
Nickel	6.49E-06	June 2000 MER * PUF
Phosphorous	6.96E-06	September 2020 MDL
Tin	6.07E-06	September 2020 MDL
Zinc	2.47E-05	June 2000 MER * PUF

1 Emission rates were determined during the NOD process on the EWI RCRA permit renewal. All detected COPCs were modeled at the measured emission rate (MER) from the prior MPRA times the process upset factor explained below. Non-detected COPCs were modeled at either the MDL reported in the June 2000 risk burn (RB), or the MDL reflected by the current TestAmerica laboratory capabilities and the stack gas flow rate measurements collected during the June 2000 RB.

2 Consistent with the prior MPRA, all actual measured emissions were adjusted by a process upset factor (PUF) to account for increased emissions during process upsets. The same PUF was used in this assessment as was used in the prior MPRA.

3 Rate shown is reported as the 2,3,7,8-TCDD toxic equivalent.

2.3 HUMAN HEALTH TOXICITY FACTORS

Human health toxicity factors were used in the MPRA to calculate the total incremental risk and hazard to selected receptors. The chronic exposure toxicity factors for each COPC are identified in Table 2-3 and were obtained from the USEPA Region 3 regional screening level (RSL) tables dated May 2020 as directed by VDEQ. Acute inhalation exposure criteria (AIEC) were obtained from the National Oceanic and Atmospheric Administration's (NOAA's) Protective Action Criteria (PACs), which is hierarchy-based system of the three common public exposure guideline systems: acute exposure guideline levels (AEGLs), emergency response planning guidelines (ERPGs), and temporary emergency exposure limits (TEELs). For determination of total incremental risk, data was collected on the cancer slope factors (CSFs) for ingestion and inhalation of each COPC. In some cases, separate data on an inhalation CSF was not available. In these cases, the CSF for ingestion was applied if the COPC is classified as a potential carcinogen via the inhalation pathway. For determination of total incremental hazard, data was collected on reference doses (RfDs) and reference concentrations (RfCs). The reference doses used were for ingestion of food and ingestion of drinking water. RfCs apply to hazard resulting from inhalation of COPCs.

TABLE 2-3
HUMAN HEALTH TOXICITY DATA FOR SELECTED COPCS

COPC	CANCER SLOPE FACTORS [1]			REFERENCE DOSES/CONCENTRATIONS [2]			AEGL [3]
	INGESTION	INHALATION	D. WATER	INGESTION	INHALATION	D. WATER	
Dioxins and Furans [4]							
1,2,3,4,6,7,8,9-OCDD	Use TEF approach and toxicity values provided for TCDD						7.50E-02
1,2,3,4,6,7,8,9-OCDF	Use TEF approach and toxicity values provided for TCDD						7.50E-03
1,2,3,4,6,7,8-HpCDD	Use TEF approach and toxicity values provided for TCDD						6.00E-01
1,2,3,4,6,7,8-HpCDF	Use TEF approach and toxicity values provided for TCDD						1.50E-01
1,2,3,4,7,8,9- HpCDF	Use TEF approach and toxicity values provided for TCDD						2.50E-01
1,2,3,4,7,8-HxCDD	Use TEF approach and toxicity values provided for TCDD						1.20E-03
1,2,3,4,7,8-HxCDF	Use TEF approach and toxicity values provided for TCDD						7.50E-03
1,2,3,6,7,8- HxCDD	Use TEF approach and toxicity values provided for TCDD						1.50E-02
1,2,3,6,7,8- HxCDF	Use TEF approach and toxicity values provided for TCDD						2.50E-03
1,2,3,7,8,9- HxCDD	Use TEF approach and toxicity values provided for TCDD						1.50E-02
1,2,3,7,8,9- HxCDF	Use TEF approach and toxicity values provided for TCDD						1.20E-01
1,2,3,7,8-PCDD	Use TEF approach and toxicity values provided for TCDD						2.50E-03
1,2,3,7,8- PCDF	Use TEF approach and toxicity values provided for TCDD						5.00E-02
2,3,4,6,7,8-HxCDF	Use TEF approach and toxicity values provided for TCDD						1.50E-03
2,3,4,7,8-PCDF	Use TEF approach and toxicity values provided for TCDD						5.00E-03
2,3,7,8-TCDD	1.30E+05	1.77E+05	1.30E+05	0.00E+00	0.00E+00	0.00E+00	1.50E-03
2,3,7,8-TCDF	Use TEF approach and toxicity values provided for TCDD						2.00E-03
Nitroaromatics and Energetics							
2,4-Dinitrotoluene	3.10E-01	3.12E-01	6.65E-01	2.00E-03	7.00E-03	2.00E-03	6.00E-01
2-Nitrotoluene	0.00E+00	0.00E+00	0.00E+00	9.00E-04	0.00E+00	9.00E-04	6.00E+00
3-Nitrotoluene	0.00E+00	0.00E+00	0.00E+00	1.00E-04	0.00E+00	1.00E-04	6.00E+00
4-Nitrotoluene	0.00E+00	0.00E+00	0.00E+00	4.00E-03	0.00E+00	4.00E-03	6.00E+00
HMX	0.00E+00	0.00E+00	0.00E+00	5.00E-02	0.00E+00	5.00E-02	1.90E+01
Nitroglycerin	0.00E+00	0.00E+00	0.00E+00	1.00E-04	0.00E+00	1.00E-04	1.00E-01
RDX	0.00E+00	0.00E+00	0.00E+00	4.00E-03	0.00E+00	4.00E-03	3.00E+00
Phthalates							
bis(2-ethylhexyl)phthalate	1.40E-02	8.40E-03	1.40E-02	2.00E-01	7.00E-01	2.00E-01	1.00E+01
Butylbenzyl phthalate	1.90E-03	1.90E-03	1.90E-03	2.00E-01	7.00E-01	2.00E-01	1.50E+01
Diethyl phthalate	0.00E+00	0.00E+00	0.00E+00	8.00E-01	2.80E+00	8.00E-01	1.50E+01

Table 2-3 (continued)
Human Health Toxicity Data for Selected COPCs

COPC	Cancer Slope Factors [1]			Reference Doses/Concentrations [2]			AEGL [3]
	Ingestion	Inhalation	D. Water	Ingestion	Inhalation	D. Water	
Other Semivolatile and Volatile Organics							
2,4,5-Trichlorophenol	0.00E+00	0.00E+00	0.00E+00	1.00E-01	3.50E-01	1.00E-01	3.00E+01
Aniline	5.70E-03	5.60E-03	5.60E-03	7.00E-03	1.00E-03	7.00E-03	3.05E+01
Benzoic acid	0.00E+00	0.00E+00	0.00E+00	4.00E+00	1.40E+01	4.00E+00	1.30E+01
Benzyl alcohol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E+01
Naphthalene	1.19E-01	1.19E-01	1.19E-01	2.00E-02	3.00E-03	2.00E-02	1.50E+01
Pentachloronitrobenzene	2.60E-01	2.59E-01	2.60E-01	3.00E-03	1.10E-02	3.00E-03	1.50E+00
Pentachlorophenol	1.20E-01	1.61E-02	1.05E-01	3.00E-02	1.05E-01	3.00E-02	1.50E+00
Phenol	0.00E+00	0.00E+00	0.00E+00	3.00E-01	2.00E-01	3.00E-01	1.50E+01
1,2,3-Trichlorobenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E+01
1,2-Dibromo-3-Chloropropane	7.00E+00	6.65E+00	7.00E+00	5.70E-04	2.00E-04	5.70E-04	3.00E-03
1,3-Dichloropropane	0.00E+00	0.00E+00	0.00E+00	2.00E-02	0.00E+00	2.00E-02	5.40E+00
2-Hexanone	0.00E+00	0.00E+00	0.00E+00	5.00E-03	3.00E-02	5.00E-03	1.00E+01
Acetone	0.00E+00	0.00E+00	0.00E+00	9.00E-01	3.10E+01	9.00E-01	2.00E+02
Bromochloromethane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E-02	0.00E+00	6.00E+02
Isopropylbenzene	0.00E+00	0.00E+00	0.00E+00	1.00E-01	4.00E-01	1.00E-01	5.00E+01
Methylene chloride	2.00E-03	3.50E-05	7.35E-03	6.00E-03	6.00E-01	6.00E-03	2.00E+02
n-Butylbenzene	0.00E+00	0.00E+00	0.00E+00	5.00E-02	0.00E+00	5.00E-02	3.60E+00
N-Propylbenzene	0.00E+00	0.00E+00	0.00E+00	1.00E-01	1.00E+00	1.00E-01	3.70E+00
Styrene	0.00E+00	0.00E+00	0.00E+00	2.00E-01	1.00E+00	2.00E-01	2.00E+01
tert-Butylbenzene	0.00E+00	0.00E+00	0.00E+00	1.00E-01	0.00E+00	1.00E-01	1.70E+00
Toluene	0.00E+00	0.00E+00	0.00E+00	8.00E-02	5.00E+00	8.00E-02	6.70E+01
Metals							
Aluminum	0.00E+00	0.00E+00	0.00E+00	1.00E+00	5.00E-03	1.00E+00	3.00E+00
Antimony	0.00E+00	0.00E+00	0.00E+00	4.00E-04	1.40E-03	4.00E-04	1.50E+00
Cadmium	3.80E-01	6.30E+00	3.80E-01	1.00E-03	1.00E-05	5.00E-04	1.00E-01
Chromium (as hexavalent)	5.00E-01	2.94E+02	5.00E-01	3.00E-03	1.00E-04	3.00E-03	0.00E+00
Copper	0.00E+00	0.00E+00	0.00E+00	4.00E-02	1.40E-01	4.00E-02	3.00E+00
Iron	0.00E+00	0.00E+00	0.00E+00	7.00E-01	0.00E+00	7.00E-01	3.20E+00

TABLE 2-3 (CONTINUED)
HUMAN HEALTH TOXICITY DATA FOR SELECTED COPCS

COPC	CANCER SLOPE FACTORS [1]			REFERENCE DOSES/CONCENTRATIONS [2]			AEGL [3]
	INGESTION	INHALATION	D. WATER	INGESTION	INHALATION	D. WATER	
Metals (continued)							
Lead	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-01
Mercury	0.00E+00	0.00E+00	0.00E+00	8.60E-05	3.00E-04	8.60E-05	1.80E-03
Nickel	0.00E+00	8.40E-01	0.00E+00	2.00E-02	2.00E-04	2.00E-02	6.00E-03
Phosphorous	0.00E+00	0.00E+00	0.00E+00	2.00E-05	7.00E-05	2.00E-05	2.70E-01
Tin	0.00E+00	0.00E+00	0.00E+00	6.00E-01	2.10E+00	6.00E-01	6.00E+00
Zinc	0.00E+00	0.00E+00	0.00E+00	3.00E-01	5.30E+00	3.00E-01	6.00E+00

1 All cancer slope factors are presented in the units of $(mg/kg\text{-}BW/day)^{-1}$.

2 All reference doses are presented in the units of mg/kg-BW/day. All reference concentrations are presented in the units of mg/m^3.

3 All acute exposure guideline levels (AEGLs) are presented in the units of mg/m^3.

4 Values shown are for tetrachlorodibenzo(p)dioxin (TCDD). The concentration of these COPCs is adjusted to TCDD toxic equivalents (TEQs) using toxicity equivalent factors (TEFs).

2.4 ECOLOGICAL TOXICITY REFERENCE VALUES

The measure of effect for the SLERA is based on established toxicity reference values (TRVs). TRVs are ecological criteria associated with either no adverse or only a low level of adverse effect for protection of specific communities (*e.g.*, sediment guidelines protective of benthic invertebrates) or guilds. Some TRVs are media based and others are ingestion based; generally, the ingestion based TRVs are only available for higher trophic level species such as mammals and birds. For lower tropic level species, generally only the media-based TRVs can be used to assess the expected effect on the species.

The USEPA's SLERAP provided a compilation of TRV data for those COPCs typically included in risk assessments for hazardous waste combustion facilities. However, VDEQ indicated that those TRVs are outdated and should not be used for the SLERA. In lieu of using those TRVs, VDEQ recommended that the following sources be consulted for this SLERA (in order of preference):

- USEPA Region 3's Biological Technical Assistance Group (BTAG) TRVs;
- Oak Ridge National Laboratory's (ORNL's) Toxicological Benchmarks for Wildlife;
- National Oceanic and Atmospheric Association (NOAA) Screening Quick Reference Tables (SQuiRTs);
- USEPA's Interim Ecological Soil Screening Level (ECO-SSL); and
- USEPA's ECOTOXicology Knowledgebase (ECOTOX).

A preliminary list of TRVs for this assessment was provided in the MPRA Protocol for RFAAP's open burning ground (RFAAP, 2019b). Prior to completion of this SLERA, BAE queried each of the above references to ensure that the most current TRV was being used for the assessment. In addition to the references cited above, BAE also referenced the SLERA that VDEQ performed for the open burning ground. This reference was provided top priority in the TRV hierarchy, followed by the hierarchy described above. The final list of TRVs used in this SLERA is provided in Table 2-4. The source of each TRV is cited in supporting data provided in Table D-3 of Appendix D. Links to the referenced sources are provided in the footnotes to Table 2-4.

TABLE 2-4
SUMMARY OF ECOLOGICAL TRVS FOR THE SLERA

COMPOUND OF POTENTIAL CONCERN	COMMUNITY RECEPTORS [1]				WILDLIFE RECEPTORS [1]	
	FRESHWATER (MG/L)	FRESHWATER SEDIMENT (MG/KG)	TERRESTRIAL PLANT (MG/KG)	SOIL INVERTEBRATE (MG/KG)	MAMMAL (MG/KG/DAY)	BIRD (MG/KG/DAY)
Dioxins and Furans						
1,2,3,4,5,7,8,9-OCDD	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,4,6,7,8,9-OCDF	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,4,6,7,8-HpCDD	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,4,6,7,8-HpCDF	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,4,7,8,9- HpCDF	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,4,7,8-HxCDD	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,4,7,8-HxCDF	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,6,7,8- HxCDD	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,6,7,8- HxCDF	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,7,8,9- HxCDD	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,7,8,9- HxCDF	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,7,8-PCDD	Use TEF approach and toxicity TRVs provided for TCDD					
1,2,3,7,8- PCDF	Use TEF approach and toxicity TRVs provided for TCDD					
2,3,4,6,7,8-HxCDF	Use TEF approach and toxicity TRVs provided for TCDD					
2,3,4,7,8-PCDF	Use TEF approach and toxicity TRVs provided for TCDD					
2,3,7,8-TCDD	3.10E-12	8.50E-07	NA	5.00E+00	3.00E-07	1.40E-05
2,3,7,8-TCDF	Use TEF approach and toxicity TRVs provided for TCDD					
Nitroaromatics and Energetics						
2,4-Dinitrotoluene	4.40E-02	4.16E-02	NA	NA	NA	NA
2-Nitrotoluene	NA	NA	NA	NA	NA	NA
3-Nitrotoluene	7.50E-01	NA	NA	NA	NA	NA
4-Nitrotoluene	1.90E+00	NA	NA	NA	NA	NA
HMX	1.50E-01	NA	NA	NA	NA	NA
Nitroglycerin	1.38E-01	4.90E-03	2.10E+01	NA	9.64E+01	NA
RDX	3.60E-01	1.30E-02	NA	NA	NA	NA

TABLE 2-4 (CONTINUED)
SUMMARY OF ECOLOGICAL TRVS FOR THE SLERA

COMPOUND OF POTENTIAL CONCERN	COMMUNITY RECEPTORS [1]				WILDLIFE RECEPTORS [1]	
	FRESHWATER (MG/L)	FRESHWATER SEDIMENT (MG/KG)	TERRESTRIAL PLANT (MG/KG)	SOIL INVERTEBRATE (MG/KG)	MAMMAL (MG/KG/DAY)	BIRD (MG/KG/DAY)
Phthalates						
bis(2-ethylhexyl)phthalate	1.60E-02	1.80E-01	NA	NA	2.50E+00	1.10E+00
Butylbenzyl phthalate	1.90E-02	1.09E-01	NA	NA	NA	NA
Diethyl phthalate	2.10E-01	6.03E-01	1.00E-02	NA	6.96E-02	NA
Other Semivolatile and Volatile Organics						
2,4,5-Trichlorophenol	NA	NA	NA	NA	NA	NA
Aniline	2.20E-03	NA	NA	NA	NA	NA
Benzoic acid	4.20E-02	6.50E-01	NA	NA	NA	NA
Benzyl alcohol	8.60E-03	5.20E-02	NA	NA	NA	NA
Naphthalene	1.10E-03	1.80E-01	1.00E+00	2.90E+01	2.50E+00	2.90E+02
Pentachloronitrobenzene	NA	NA	NA	NA	NA	NA
Pentachlorophenol	5.00E-04	5.04E-01	NA	NA	NA	NA
Phenol	1.80E-01	4.20E-01	7.00E-01	3.00E-01	6.00E+01	NA
1,2,3-Trichlorobenzene	8.00E-03	8.58E-01	NA	NA	NA	NA
1,2-Dibromo-3-Chloropropane	NA	NA	NA	NA	NA	NA
1,3-Dichloropropane	NA	NA	NA	NA	NA	NA
2-Hexanone	9.90E-02	NA	NA	NA	NA	NA
Acetone	1.50E+00	3.60E-02	NA	NA	2.80E+00	2.01E+02
Bromochloromethane	NA	NA	NA	NA	NA	NA
Isopropylbenzene	2.60E-03	9.00E-02	NA	NA	NA	NA
Methylene chloride	9.81E-02	2.68E-01	1.60E+03	NA	1.60E+00	NA
n-Butylbenzene	NA	NA	NA	NA	NA	NA
N-Propylbenzene	1.28E-01	7.20E-01	NA	NA	NA	NA
Styrene	7.20E-02	5.59E-01	3.00E+02	1.20E+00	NA	NA
tert-Butylbenzene	NA	NA	NA	NA	NA	NA
Toluene	2.00E-03	1.22E+03	2.00E+02	7.50E+01	3.90E+00	NA

TABLE 2-4 (CONTINUED)
SUMMARY OF ECOLOGICAL TRVS FOR THE SLERA

COMPOUND OF POTENTIAL CONCERN	COMMUNITY RECEPTORS [1]				WILDLIFE RECEPTORS [1]	
	FRESHWATER (MG/L)	FRESHWATER SEDIMENT (MG/KG)	TERRESTRIAL PLANT (MG/KG)	SOIL INVERTEBRATE (MG/KG)	MAMMAL (MG/KG/DAY)	BIRD (MG/KG/DAY)
Metals						
Aluminum	8.70E-02	1.80E+04	5.00E+01	6.00E+02	2.93E-01	1.10E+02
Antimony	3.00E-02	2.00E+00	5.00E+00	7.80E+01	1.90E-02	NA
Cadmium	2.50E-04	9.90E-01	3.20E+01	1.42E+02	2.71E-01	1.45E+00
Chromium (as hexavalent)	1.10E-02	4.34E+01	1.00E+00	4.00E-01	9.20E-01	9.20E-01
Copper	9.00E-03	3.16E+01	7.00E+01	8.00E+01	4.30E+00	4.70E+01
Iron	3.00E-01	2.00E+04	NA	NA	NA	NA
Lead	2.50E-03	3.58E-01	1.15E+02	1.68E+03	2.24E+00	1.13E+00
Mercury	2.60E-05	1.80E-01	NA	NA	NA	NA
Nickel	5.20E-02	2.27E+01	3.80E+01	2.80E+02	1.70E+00	6.71E+00
Phosphorous	1.00E-04	NA	NA	NA	NA	NA
Tin	7.30E-02	NA	5.00E+01	NA	3.60E+00	6.80E+00
Zinc	1.20E-01	1.21E+02	1.60E+02	1.20E+02	4.49E+01	1.45E+01

1 Toxicity values reported as "NA" (none available) indicate that no TRVs were found for this compound in the referenced sources.

2 TRVs from EPA Region III Biological Technical Assistance Group (BTAG), available at https://www.epa.gov/risk/biological-technical-assistance-group-btag-screening-values. Listed values are No Observed Adverse Effect Level (NOAEL).

3 TRVs from National Oceanographic and Atmospheric Administration's 2008 Screening Quick Reference Tables (SQuiRTs), available at https://response.restoration.noaa.gov/sites/default/files/SQuiRTs.pdf. Listed values are Low Observed Adverse Effect Level (LOAEL).

4 TRV source ORNL Toxicological Benchmarks for Wildlife: 1996 Revision, available at https://rais.ornl.gov/documents/tm86r3.pdf. Listed values are No Observed Adverse Effect Level (NOAEL). Range provided is for all listed species of the listed type; the ORNL benchmarks provide TRVs for up to 9 mammals and 11 birds for each listed chemical. As the listed values are a function of body weight, the low NOAELs are generally associated with the highest-weight species in the group (white-tailed deer for mammals and wild turkeys for birds) and the high NOAELs are generally associated with the lowest-weight species in the group (little brown bats for mammals and rough-winged swallows for birds).

5 TRVs from USEPA's Eco-SSLs, accessed at https://www.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents. For mammalian and bird species, the Eco-SSLs are determined for multiple species and are calculated as a function of body weight and ingestion rate. The values shown represent the range of values across all listed species of the listed type.

6 TRVs from USEPA's ECOTOX Database, accessed at http://www.epa.gov/ecotox/. Listed values are No Observed Adverse Effect Level (NOAEL) or No Observed Effect Concentration (NOEC). For mammalian and bird species, the EcoTox are determined for multiple species and are presented as mg/kg-BW/day. The values shown represent the range of values across all listed species of the listed type.

3.0 AIR MODELING

The first step in the MPRA process is the modeling of air emissions from the EWIs. The protocol for this modeling effort was described in the *Air Modeling Protocol for the Radford Army Ammunition Plant Hazardous Waste Incinerators* submitted to VDEQ in September 2019 (RFAAP, 2019a). The modeling protocol was approved by VDEQ in a letter dated November 4, 2019 (VDEQ, 2019). A memorandum documenting the process and the results of the air modeling was submitted to VDEQ in December 2019 and was revised in February 2020 (RFAAP, 2020). Approval of the air modeling was subsequently received on February 20, 2020 (VDEQ, 2020). This section details the air modeling process that was used by RFAAP and approved by VDEQ. A complete copy of the air modeling files for this MPRA were provided previously under separate cover with the 2020 air modeling report (RFAAP, 2020).

3.1 METHODOLOGY

The modeling of the EWI operations at RFAAP was completed using the most recent version of the AMS/EPA Regulatory Model (AERMOD version 19191) released on August 21, 2019, and available from USEPA's Support Center for Regulatory Air Models (SCRAM). While the HHRAP guidance was developed specifically for a precursor model (Industrial Source Complex Short-term – ISCST3), the AERMOD model has been designated by USEPA and VDEQ as the replacement for ISCST3 and, therefore, is the most acceptable and appropriate model to apply the HHRAP techniques to the EWIs. AERMOD is a Gaussian plume model that uses cloud/plume rise, dispersion, and deposition algorithms to predict the downwind transport and dispersion of pollutants released by many source types including hazardous waste combustors.

3.2 MODELED SCENARIOS

As specified in the modeling protocol, the AERMOD modeling included one model run and five years of VDEQ-provided meteorological data to predict the vapor and particulate air concentrations and deposition rates resulting from simultaneous operation of the two EWIs at the RFAAP. The model output provided concentration and deposition values for 1-hour and annual averaging periods over an extensive receptor grid.

The two EWIs were modeled as if operating simultaneously at maximum production rates. A summary of the exhaust parameters modeled for each incinerator stack is provided in Table 3-1.

TABLE 3-1
INCINERATOR EXHAUST PARAMETERS

INCINERATOR PARAMETERS		INCINERATOR 440	INCINERATOR 441
Location	Easting (meters)	540056.8	540116.0
	Northing (meters)	4116946.6	4116978.7
Base Elevation	meters	518.5	518.5
Modeled Emission Rate	gram/second	1.0	1.0
Stack Height	meters	10.67	10.67
Exit Diameter	meters	0.605	0.605
Exhaust Temperature [1]	degrees Kelvin	356	356
Exit Velocity [1]	meters/second	12	12

[1] As measured during the last comprehensive performance test (CPT) on the incinerators, conducted in 2015. (RFAAP, 2015)

As per the HHRAP, a unitized emission rate of 1 gram per second (g/s) was used in all modeling runs. This surrogate emission rate was then adjusted based on site-specific emission rates for each of the COPCs specified in Section 2. The unitized emission rate allows for significantly fewer modeling runs. The output from the unitized emission runs can easily be adjusted in a spreadsheet application determine COPC-specific concentrations and deposition values.

3.3 MODELED EMISSION PHASES

COPCs are emitted from the incinerator exhaust in a combination of three different phases: particle phase, particle-bound phase, and vapor phase. The different phases behave differently under environmental conditions due to differences in physical characteristics. Compounds emitted to the atmosphere from the RFAAP EWIs were characterized by one of three phase types. To account for all COPCs, the AERMOD model was modeled separately for each the phases as:

- COPCs that tend to be emitted in the vapor or gaseous phase were characterized via the AERMOD vapor-phase modeling, utilizing the modeled vapor phase air concentrations, dry vapor deposition values, and wet vapor deposition values. The vapor phase simulations were applied to most organic COPCs, with the exception of those organics not befitting the vapor phase such as polynuclear aromatic hydrocarbons (PAHs).
- COPCs that tend to be emitted in the particle phase were characterized via the AERMOD particle-phase modeling, utilizing the modeled particle phase air concentrations, and dry, wet, and total particle deposition values. The particle phase simulations were applied to all inorganic COPCs, as well as to the organic COPCs with a vapor phase fraction of less than 0.05 such as PAHs.
- COPCs that tend to be emitted in the particle bound phase were characterized via the AERMOD particle bound modeling, utilizing the modeled particle bound air concentrations, and dry, wet, and total particle-bound deposition values. The particle-bound phase included those compounds where a portion of the exhausted vapor condenses onto particle surfaces.

The particle phase and particle-bound phase modeling included particle sizing information to allow AERMOD to calculate the deposition parameters and to take into account plume depletion. The particle sizes applied are provided in Table 3-2 and are based on information obtained during prior testing of the incinerators in June 2000. This particle sizing data was used in the AERMOD input files via the SOURCE keywords PARTDIAM, MASSFRAX, and PARTDENS

TABLE 3-2
PARTICLE SIZE DATA FOR THE HAZARDOUS WASTE INCINERATORS

PARTICLE SIZE RANGE (MICRON)		AVERAGE PARTICLE DIAMETER (MICRON)	PARTICULATE MATTER MASS FRACTION	PARTICLE-BOUND SURFACE AREA FRACTION
0.0001	0.4	0.252	0.3552	0.684
0.4	0.5	0.452	0.16	0.1724
0.5	0.9	0.719	0.111	0.0752
0.9	1.8	1.40	0.1162	0.0405
1.8	2.8	2.34	0.0703	0.01465
2.8	4.1	3.49	0.04	0.005579
4.1	6.1	5.16	0.0109	0.001027
6.1	937	8.03	0.0103	0.000624
9.7	20	15.4	0.1261	0.00398

For the vapor phase modeling, the following SOURCE and CONTROL keywords were used:

- SOURCE keyword: GASDEPOS where numerated monthly values for the seasonal category were input for GDSEASON and the land use values in GDLANUSE conforming with those described in Table 2-4 in Section 2.2.2 were applied to the various 36 downwind sectors.
- CONTROL keywords: CONC GDSEASON GDLANUSE DDEP WDEP

The SOURCE keyword GASDEPOS was applied based on general characteristics of the vapor phase COPCs using appropriate values for the diffusivity in air, diffusivity in water, cuticular resistance, and Henry's Law constant for the surrogate compound toluene. Toluene is a compound likely to be emitted from the process and the values used were obtained from those listed in Wesely, *et.al.*, 2002 and are respectively 0.08054, 0.9097E5, 1.74E4, and 6.8E2. These values were used for each incinerator emission source and input using the SO GASDEPOS AERMOD calls.

The seasonal patterns for each of the twelve-month periods were also input into AERMOD using the GDSEASON keyword and included the following input:

CO GDSEASON 4 3 5 5 1 1 1 1 2 2 3 4

The seasonal values in AERMOD correspond with the following five distinct periods

1. Midsummer and lush vegetation
2. Autumn with unharvested cropland
3. Late autumn after frost and harvest, or winter with no snow
4. Winter with snow on ground and generally continuous snow coverage
5. Transitional spring with partial green coverage or short annuals.

Modeling of particulate phase COPCs and particle-bound COPCs invoked slightly different AERMOD particle fractions with the particle phase using the particle mass fraction values in Table 3-2 and the particle-bound phase using the surface area fraction values in Table 3-2, so as to return the appropriate values to support the particulate based risk calculations. Each particle phase AERMOD run involved the SOURCE keywords needed to provide the particle sizing and method values and the following CONTROL keywords: DFAULT CONC DEPOS DDEP WDEP DRYDPLT WETDPLT.

3.4 Building Downwash Analysis

The incinerator stacks are located atop buildings and are adjacent to other buildings and structures. As these building are at least 40 percent of the height of each stack, turbulent eddies may be formed downwind of the buildings and structures. These eddies can impact the dispersion of the plume from each incinerator. Therefore, it is necessary to assess the impacts of building downwash on the plume from each incinerator.

Should a plume with relatively low buoyancy or momentum flux encounter a turbulent eddy of sufficient size or intensity, the encountered turbulent wake can alter the plume dynamics typically reducing the plume height from what would have been without the turbulent eddy. This is especially true for stacks that have a low height relative to adjacent roofs, or stacks at roof edges where interactions with building wakes can trap emitted plumes within the building wake and return elevated near source ground level concentrations. As eddy effects result from building/stack orientation and winds, each wind direction can have a different potential eddy generating capability.

The different wind direction turbulence inducing dimensions of building height, width, and distance of stack to edge are developed through use of the USEPA Building Profile Input Program (BPIP). The USEPA recently released an updated BPIP program in DRAFT status (v. 19191_DRFT). Specific modifications were made in the draft release to address rectangular buildings and building tiers, and to refine the projected width calculations for these rectangular structures. However, because this new release is in DRAFT form it cannot be used in a regulatory assessment. Therefore, the current BPIP release (v. 04274) was used in this analysis.

The building footprint corner coordinates and building heights input to BPIP are provided in Table 3-3. These coordinates and parameters were used with the location and height of each incinerator stack in the BPIP program to produce the wind direction specific building dimensions used in the modeling analysis.

The stacks themselves are less than the good engineering practice (GEP) stack height, where GEP is determined as either 65 meters or from a formula (1.5 H + L), where H is the building height and L is the lesser of the height or the maximum projected width. Therefore, there is no need to limit the height of the stacks in AERMOD to the GEP height.

TABLE 3-3
BUILDINGS, HEIGHTS, AND CORNER COORDINATES USED IN GEP ANALYSIS

BUILDING NUMBER	HEIGHT ABOVE GRADE (METER)	BASE ELEVATION (METERS) [1]	UTM COORDINATE EASTING	UTM COORDINATE NORTHING
Building 440	6.7	518.5	540053.2	4116951.1
			540065.7	4116951.4
			540065.9	4116941.3
			540053.5	4116940.9
Building 441	6.7	518.5	540110.9	4116978.5
			540118.6	4116988.3
			540126.5	4116982.3
			540118.5	4116972.1
Building 429	7.0	518.5	540013.9	4116959.9
			540015.1	4116954.4
			540027.6	4116956.8
			540028.2	4116962.0
Building 430_1	6.7	518.5	539996.8	4117022.4
			539997.4	4117021.2
			540005.4	4117023.3
			540005.1	4117024.5
Building 430_2	6.7	518.5	539997.4	4117021.2
			539999.3	4117013.2
			540011.8	4117017.2
			540009.9	4117024.2
Building 442_1	7.4	518.5	540059.5	4117041.0
			540062.5	4117031.8
			540073.2	4117034.6
			540070.4	4117044.0

TABLE 3-3 (CONTINUED)
BUILDINGS, HEIGHTS, AND CORNER COORDINATES USED IN GEP ANALYSIS

BUILDING NUMBER	HEIGHT ABOVE GRADE (METER)	BASE ELEVATION (METERS) [1]	UTM COORDINATE EASTING	UTM COORDINATE NORTHING
Building 442_2	7.4	518.5	540062.5	4117031.8
			540064.3	4117027.2
			540075.9	4117026.0
			540073.2	4117034.6
Building 442_3	7.4	518.5	540070.4	4117044.0
			540075.0	4117027.7
			540081.1	4117029.1
			540076.2	4117045.5
Building 442_4	7.4	518.5	540076.2	4117045.5
			540079.9	4117029.1
			540085.4	4117034.3
			540081.7	4117047.4

1 Relative to height above mean sea level.
2. Universal Transverse Mercator, Zone 17, NAD83.

3.5 LAND USE CLASSIFICATION AND DISPERSION COEFFICIENTS

The USEPA GAQM presents a discussion of rural and urban land use determinations. For this analysis, the land use was determined using a technique proposed by Auer in Correlation of Land Use and Cover with Meteorological Anomalies. This method is recommended in the *Regional Workshop on Air Quality Modeling: A Summary Report* developed by USEPA. The method is used to classify the area within a three-kilometer radius of the source as urban or rural. The Auer method uses twelve different classifications for land use. In this method, areas of industrial, commercial, and compact residential land use are designated urban. Low density residential, water surfaces, agricultural, undeveloped, and natural areas are designated rural. According to USEPA procedure, if more than 50 percent of an area circumscribed by a 3-km radius about the source is classified urban, then urban coefficients should be used; otherwise, the area is considered rural.

The land use for the assessment area was evaluated using data provided by the National Land Cover Database developed by the Multi-Resolution Land Characteristics Consortium. The land use within the immediate region is primarily forested land, with intermittent sections of pastures and fields used for crop production. Table 3-4 provides the relative percentage that each land use classification represents within this 3-km radius. As shown in the table, most of the surrounding land meets the rural classifications established under the USEPA procedure. Therefore, rural dispersion coefficients apply to the area.

TABLE 3-4
LAND USE PROPORTIONS WITHIN THE ASSESSMENT AREA

LAND USE TYPE	CATEGORY	PERCENTAGE
Deciduous forest	Rural	28.3%
Pasture hay	Rural	20.3%
Developed, low intensity	Rural	19.5%
Developed, open space	Rural	11.3%
Open water	Rural	7.2%
Developed, medium intensity	Urban	5.7%
Evergreen forest	Rural	3.4%
Developed, high intensity	Urban	2.0%
Cultivated crops	Rural	1.6%
Mixed forest	Rural	0.5%
Grassland/herbaceous	Rural	0.3%
Total Rural		**69.2%**
Total Urban		**30.8%**

As noted previously, to account for varying land use effects on gaseous dry deposition parameterizations, the AERMOD model also requires land use determinations for each sector of the 36, 10-degree sectors within the 3-km radius of the modeled source locations. The tabulated land use determinations for each of the 36 are provided in Table 3-5.

TABLE 3-5
LAND USE SELECTIONS FOR EACH SECTOR OF THE 36 SECTORS IN 3-KM RADIUS

SECTOR	CATEGORY	DESCRIPTION
1	2	Agricultural land
2	2	Agricultural land
3	2	Agricultural land
4	2	Agricultural land
5	4	Forest
6	4	Forest
7	4	Forest
8	4	Forest

TABLE 3-5 (CONTINUED)
LAND USE SELECTIONS FOR EACH SECTOR OF THE 36 SECTORS IN 3-KM RADIUS

SECTOR	CATEGORY	DESCRIPTION
9	2	Agricultural land
10	2	Agricultural land
11	4	Forest
12	3	Rangeland
13	3	Rangeland
14	3	Rangeland
15	1	Urban land, no vegetation
16	1	Urban land, no vegetation
17	1	Urban land, no vegetation
18	3	Rangeland
19	3	Rangeland
20	3	Rangeland
21	3	Rangeland
22	3	Rangeland
23	3	Rangeland
24	3	Rangeland
25	4	Forest
26	3	Rangeland
27	2	Agricultural land
28	2	Agricultural land
29	2	Agricultural land
30	2	Agricultural land
31	2	Agricultural land
32	2	Agricultural land
33	2	Agricultural land
34	2	Agricultural land
35	2	Agricultural land
36	2	Agricultural land

3.6 Receptor Grid and Terrain Grid Data

The receptor pathway specifies sets or arrays of receptor grid nodes identified by Universal Transverse Mercator (UTM) coordinates for which the air model generates estimates of ambient air concentrations and deposition rates. The HHRAP recommends that, at a minimum, an array of receptor grid nodes covering the area within 10 kilometers, centered at the source be used. This receptor grid should consist of a Cartesian grid with nodes spaced not greater than 100 meters apart, extending from the source out to 3 kilometers. For distances from 3 kilometers out to 10 kilometers, the spacing can be increased to not greater than 500 meters. Additionally, fenceline receptors, which are receptors located along the property boundary, should be spaced at intervals of no greater than 100 meters along the fenceline in order to estimate maximum annual concentrations and deposition rates at the property boundary.

The receptor grid used for this analysis followed the recommendations described in the HHRAP. The receptors were spaced at 100-meter intervals beginning at the fenceline and extending outward to 3 kilometers from the RFAAP boundary. In the region from 3 kilometers to 10 kilometers from the boundary, the receptor spacing interval was 500 meters. Using this receptor spacing generated a grid of 9,720 individual receptor locations for evaluation in the air modeling study.

Terrain elevations were assigned to each receptor point using data from the USGS National Elevation Dataset (NED). The terrain data was processed in the AERMOD terrain processor AERMAP (18081). All coordinate locations for modeling were developed in North American Datum of 1983 (NAD 83) Zone 17. As the maximum modeled concentrations and deposition values occurred within a receptor spacing of 100 meters, no further refinement to receptor spacing was required.

3.7 Model Options

In order to ensure the necessary data is provided from AERMOD to run the MPRA calculations, various options were specified in the OUTPUT pathway to enable the post-processing needed to convert the AERMOD output concentrations and deposition rates to COPC-specific values. A description of steps and output of results is provided below.

3.7.1 Averaging Times

Because the MPRA is concerned primarily with long-term (chronic) health risks, the averaging time in the AERMOD model inputs was specified as *annual*. In addition to the annual averaging period and because the risk assessment is also concerned with acute effects, the hourly averaging period was also included.

3.7.2 Unit Operating Hours

All modeling was conducted assuming that the incinerators both operate 24 hours per day, 7 days a week, 365 days per year. This approach was taken to provide a conservative and operationally flexible assessment of risk resulting from the EWIs. As the incinerators do not normally operate simultaneously over the entire year, this assumption of operating hours provides an extremely conservative estimate of risk.

3.8 Modeling Results

The AERMOD model was run for each year of meteorological data using the input parameters described and documented in prior sections. The model was run in three separate iterative processes to include the simulation of COPC emissions from each of the hazardous waste incinerators for the various physical characteristics associated with:

- Vapor phase COPCs using the gas concentration and deposition parameters;
- Particle phase COPCs using the particle concentration and mass fraction deposition parameters;
- Particle bound COPCs using the particle bound concentration and surface area fraction deposition parameters.

The model was run with invariant incinerator exhaust parameters (static output) and emissions to the atmosphere and subsequent downwind transport were simulated for each hour of the year long meteorological record for each of the five-year periods. Direction specific building dimensions were applied in the modeling to account for potential downwash of nearby buildings and structures.

Each hourly value at each of the 9,720 receptor locations was saved and formed by AERMOD into appropriate annual average concentration and deposition values based on unitized emission rates. AERMOD plot output files were developed so that the maximum annual concentration and deposition (total, dry, and wet) values were calculated for each receptor location.

The resulting output was queried against the land use data for the surrounding area to determine those locations with the maxima average values over the five-year period that were suitable for each of the three main exposure scenarios (*i.e.,* subsistence farmer, resident, and subsistent fisher). The selection of these locations was documented in a memorandum provided to VDEQ in April 2020. Revisions to the memorandum were made in May 13, 2020, in order to receive VDEQ approval of the receptor locations, which was provided on May 20, 2020. A summary of the air modeling results is provided graphically in Figures 3-1 through 3-12. A complete copy of all air modeling files was provided to VDEQ in December 2019 and was revised in February 2020 (RFAAP, 2020). Final approval of the air modeling was provided by VDEQ prior to this assessment being conducted (VDEQ, 2020).

As discussed further in Section 4, the MPRA assesses risk for various members of the population in different exposure scenarios. Each exposure scenario utilizes the air modeling results from various locations from throughout the assessment area based on the activity that the receptor being assessed is engaging in. The specific air modeling values utilized for each exposure scenario are provided in Section 4. The values utilized are consistent with those approved by VDEQ in their approval dated May 20, 2020 (VDEQ, 2020).

3.9 MODEL OUTPUT CONVERSION

As previously noted, the modeling was completed in accordance with the HHRAP guidance and used unitized emission rates (1 g/s) as surrogates for the emitted COPCs. As each EWI modeled used the 1 g/s emission rate, the results of the AERMOD runs are expressed in micrograms per cubic meter per gram per second ($\mu g/m^3$-g/s) for concentration values and grams per square meter per year per gram per second (g/m^2/yr-g/s) for deposition values. Values in these units were directly output for each receptor location for each year of meteorological data and made available for subsequent post-processing.

These unitized air modeling results can be converted to COPC specific values by multiplying the modeled output value (*i.e.,* concentration or deposition rate) by the COPC specific emission rate provided in Section 2 through use of equation 3-4 in the HHRAP guidance. Once determined, the COPC-specific concentration and deposition values can then be used directly in the calculation of risk through the various uptake pathways and durations of exposure based on sensitive receptor locations.

4.0 EXPOSURE SCENARIOS

Before proceeding with the risk and hazard calculations, the surrounding land use and human activities were evaluated, and potential locations for each exposure scenario were identified. This section discusses the exposure scenarios that were evaluated in the MPRA and the methodology used to select the location for the assessment. Information is provided on the exposure setting characterization, the selected exposure scenarios, and the location of each.

4.1 CHARACTERIZATION OF EXPOSURE SETTING

A characterization of the exposure setting is necessary to determine the potential receptors and their expected types of exposure to the constituents being evaluated in the MPRA. Such a characterization includes identifying the potential receptors and the methods for exposure to the COPCs based on both current and reasonable future human activities and land uses. To complete the characterization, human activities, land use, and terrain characteristics, as well as the waterbody and watershed arrangement, were reviewed.

4.1.1 LAND USE AND HUMAN ACTIVITY

RFAAP occupies approximately 4,100 acres in Pulaski and Montgomery counties in southwest Virginia. The New River separates Pulaski and Montgomery Counties and divides the RFAAP into two portions commonly known as the Horseshoe Area and the Main Manufacturing Area. Nearby towns of Blacksburg, Christiansburg, and Roanoke serve as the primary population centers in the area. United States Census Bureau (USCB) data from the 2010 census was reviewed to determine local population demographics (USCB, 2010). Table 4-1 presents an overview of some of this data. As shown in the table, the majority of the population in both counties consists of adults between the ages of 18 and 65. The large discrepancy between the median age in Montgomery and Pulaski counties is largely contributed to the high student population attending Virginia Tech, with over 30,000 students enrolled in either undergraduate, graduate, or professional programs in 2010 (SCHEV, 2019). In comparison, Radford University, which is in Pulaski County, had a total enrollment of just over 9,000 students in 2010 (SCHEV, 2019).

TABLE 4-1
POPULATION DEMOGRAPHICS

PARAMETER	MONTGOMERY COUNTY	PULASKI COUNTY
Total population	94,392	34,872
Persons per square mile	244	109
Median age	27 years old	44 years old
Persons under 5 years old	4.7 percent of population	4.9 percent of population
Persons under 18 years old	16 percent of population	19 percent of population
Persons over 65 years old	9.8 percent of population	18 percent of population
Male: Female Ratio	1.07	0.978
Households	35,767	14,821
Persons per household	2.38	2.29
Households with persons under 18	24 percent of households	27 percent of households
Households with persons over 65	18 percent of households	31 percent of households

Montgomery and Pulaski counties also have a diverse business profile. Table 4-2 provides a summary of the 2016 economic census data provided by the USCB (USCB, 2016). As shown in the table, nearly 30 percent of Montgomery County is engaged in retail or professional, scientific, or technical services, with very limited establishments engaged in agriculture, forestry, fishing, and/or hunting. Pulaski county provides a much more even distribution of business sectors, but still shows very few businesses engaged in the agricultural sector.

TABLE 4-2
BUSINESS PROFILE

PARAMETER	MONTGOMERY COUNTY	PULASKI COUNTY
Total number of establishments	1,966	592
Agriculture, forestry, fishing, and hunting	7	0
Mining, quarrying, and oil/gas extraction	4	1
Utilities	1	3
Construction	173	53
Manufacturing	49	35
Wholesale trade	41	21
Retail trade	298	95
Transportation and warehousing	35	18
Information	45	10
Finance and insurance	112	33
Real estate and rental and leasing	97	25

TABLE 4-2 (CONTINUED)
BUSINESS PROFILE

PARAMETER	MONTGOMERY COUNTY	PULASKI COUNTY
Professional, scientific, and technical services	270	39
Management of companies and enterprises	8	0
Administration and support and waste management and remediation services	98	17
Educational services	26	4
Health care and social assistance	224	71
Arts, entertainment, and recreation	35	10
Accommodation and food services	211	71
Other services	227	84
Industries not classified	5	2

A review of the National Land Cover Data Set, aerial photographs, and local zoning maps was conducted to characterize the current and potential future land use patterns throughout the assessment area. This extensive review reveals that a large fraction (nearly 50 percent) of the area consists of deciduous, pine, or mixed forests, which are unsuitable for agricultural uses unless cleared. This grouping is followed by developed areas, which represent 36 percent of the land within assessment area. Only slightly over 10 percent of the land is currently used for agriculture.

4.1.2 TERRAIN CHARACTERISTICS

The RFAAP lies within the Ridge and Valley province of the great Appalachian Mountain region that extends from the Canadian maritime provinces south to northern Georgia and Alabama. Developed in the same Paleozoic basin as the Cumberland and Allegheny Mountains, the Ridge and Valley province was developed as the thick sedimentary deposits were extensively folded and then thrust faulted during the late Paleozoic orogeny. The ridge and valley alignments were determined by the long axes of these folds, while differential erosion of underlying bedrock formations controlled the structural development of current landforms. In this modern age, the region is characterized by long, parallel, narrow, even-crested ridges rising above intervening valleys of varying size. The linear strike-ridges are largely underlain by more resistant sandstones, quartzites, and shales, whereas the valleys are underlain by less resistant limestones, dolomites, and shales.

Much of the Ridge and Valley province lies at relatively low elevation (less than 3,000 feet mean sea level (ft-MSL)), with scattered peaks along the ridges between 4,000 and 4,600 ft-MSL. Within the assessment area, elevations range from approximately 1,600 ft-MSL up to 2,900 ft-MSL. The most significant rise in terrain is found north to northwest of the facility along Brush and Cloyds Mountains, which are part of the Appalachian ridgeline. A second, much smaller terrain rise is seen east to southeast of the facility along Price Mountain. The RFAAP lies in a narrow valley between these ridges. Oriented in a northeast-southwest direction, the valley is approximately 25 miles long. The valley ranges from 8 miles wide at the southeast end to 2 miles wide in the northeast end. RFAAP lies along the New River in the relatively narrow northeastern corner of the valley.

4.1.3 Waterbodies and Watersheds

The southwestern Virginia mountains in which RFAAP is located are drained by west or south-flowing streams of the Ohio and Tennessee River systems, principally the New River, the Clinch River, the Powell River, and the forks of the Holston River. The New River actually flows through the RFAAP, dividing the Horseshoe and main plant areas. The systems within the assessment area drain through 12 hydrologic units that all empty to the New River, the James River, and the Roanoke River. Because data on the flow and depth of each waterbody is limited, the MPRA only focused on those waterbodies with United States Geological Survey (USGS) or community monitored stream characteristics. In addition, the watershed of each waterbody was limited to the affected watershed located within the assessment area. Table 4-3 provides a summary of the hydrogeological data for each waterbody that was included in the assessment. A separate, discrete set of receptors was not required to capture impact to the identified waterbodies and watersheds; the main receptor grid discussed previously provided adequate coverage, with at least one or more receptors falling within or near each identified waterbody. RFAAP utilized geographic information systems to identify those receptors in each watershed and determined the total impact to each watershed accordingly.

4.1.4 Special Subpopulations

As with most communities, the population surrounding the RFAAP consists of several groups of people that may be more susceptible to the effects from the incinerator emissions than the general population. These include children that attend local elementary schools and day cares, children and adult patients at local hospitals, elderly persons residing at local nursing homes, and infants consuming their mother's breast milk. Table 4-3 identifies the special subpopulations found within the assessment area.

TABLE 4-3
IDENTIFICATION OF SPECIAL SUBPOPULATIONS

NAME	RECEPTOR TYPE	UTM E	UTM N
Early Challenges	Day care center	551,814	4,113,560
Christiansburg Mennonite School	Day care center	551,554	4,112,542
Cedarwood Preschool	Day care center	551,554	4,112,542
Carol's Family Day care	Day care center	548,967	4,108,859
New River Community Action	Day care center	537,715	4,109,806
Central United Methodist Preschool	Day care center	538,035	4,108,889
Radford Adventure Club	Day care center	538,227	4,108,383
Radford worship Center/Rock Club	Day care center	536,571	4,107,906
Children's Garden primary	Day care center	546,497	4,118,602
The Adventure Club	Day care center	550,305	4,121,042
Valley Interfaith Childcare	Day care center	549,064	4,118,921
St. Mary's Little Angels	Day care center	547,369	4,119,377
Commonwealth Assisted Living	Nursing home	551,762	4,112,621
Commonwealth Assisted Living	Nursing home	537,356	4,110,479
Warm Hearth Village	Nursing home	551,162	4,117,325
Carilion New River Valley Hospital	Hospital	539,467	4,109,745
LewisGale Montgomery Hospital	Hospital	552,396	4,115,835
Gilbert Linkous Elementary	Elementary school	550,979	4,120,906
Tall Oaks Montessori	Elementary school	549,298	4,118,722
Prices Fork Elementary	Elementary school	545,459	4,118,381
Kipps Elementary	Elementary school	546,497	4,118,602
McHarg Elementary	Elementary school	538,082	4,108,443
Belle Heth Elementary	Elementary school	539,279	4,109,668
Riverlawn Elementary	Elementary school	539,477	4,110,479
Belview Elementary	Elementary school	543,347	4,113,992

4.1.5 ECOLOGICAL SETTING

The surrounding land use is supportive to a wide variety of plant and animal communities. The state is located geographically such that it is a meeting ground of northern and southern flora and fauna. The presence of a wide diversity of regional and topographical vegetation sequences supports a diverse animal population. Within the assessment area, RFAAP identified potential terrestrial habitats, including primarily forested and agricultural habitats, and potential aquatic habitats, including freshwater lakes, streams, and marshes, and wetlands.

Three primary habitats were identified for the assessment area, including:

- Prairie-Like Habitat: Both the agricultural and developed areas within the assessment area have plant life comprised primarily of grasses and shrubs and have animal species common to open fields and grasslands. The plants and animal species found within this area are similar to those encountered in a prairie habitat. The prairie-like habitat is also home to one of the endangered species identified in the assessment area.
- Forest Habitat: The other terrestrial habitats in the area have plant life primarily comprised of forest plants and trees and animal species common to wooded environments. The habitats represent a combination of hardwood forests, with generally similar plant and animal life. Many of the endangered or imperiled invertebrates and flowering plants are located in the forest habitat. In addition, the endangered bat species also finds its home among the trees and caves of the hardwood forest.
- Freshwater Habitat: The remaining habitat that rounds out the area is what has been deemed the freshwater habitat. This area includes the various creeks, streams, and wetland areas that makeup the assessment area. Found within these waterbodies are the endangered or imperiled insects, crustaceans, mollusks and fish in the area.

For the actual SLERA, VDEQ approved RFAAP combining the prairie-like and forest habitats into one habitat on the basis that the species and exposure routes within both habitats were largely similar. A detailed discussion of these similarities and the justification for their combination can be found in the final Multipathway Risk Assessment Protocol for the Radford Army Ammunition Plant Open Burning Grounds, revised May 2019 (RFAAP, 2019b) and approved by VDEQ that same month (VDEQ, 2019b).

4.1.5.1 Prairie Habitat

The Prairie habitat is defined in this assessment as those areas defined as agricultural, developed, or shrubland/grassland areas. It represents approximately 49 percent of the study area. While not truly a prairie, these areas, like a prairie, often include temperate grasslands and a composition of grasses, herbs and shrubs as the dominant vegetation type. Trees and shrubs are largely absent. Grazing by large mammals and farming by local populations prevent woody shrubs and trees from becoming established. A few trees such as cottonwoods, oaks and willows grow in river valleys, and a few hundred species of flowers grow among the grasses. These grasses support numerous types of terrestrial insects, such as beetles and butterflies, as well as other terrestrial invertebrates such as ticks and snails. As would be expected, the clear open fields are ideally suited for predatory birds, and the vegetation and abundant insect life support a variety of insectivorous and herbivorous birds. Numerous reptiles, such as snakes and turtles, as well as small, insectivorous and herbivorous mammals liked mice, moles, and rabbits, can be found hiding among the short grasses. In addition to the predatory birds, higher trophic level mammals such as coyotes, foxes, and weasels can be found in this short-grass prairie habitat. Except for these large predatory species, this short-grass prairie habitat shares many of the same lower trophic level species as those found in the Forest habitat.

The areas designated in the prairie habitat do not include any specifically protected ecological areas. However, *Neonympha mitchellii mitchellii*, commonly known as Mitchell's Satyr butterfly, is found in shrubland and grassland areas like those in the prairie habitat. Therefore, inclusion of this habitat in the SLERA, helps ensure protection of this endangered species.

4.1.5.2 Forest Habitat

The Forest habitat is defined in this assessment as those areas classified as some type of forest. This habitat represents approximately 48 percent of the study area. The forest habitat consists of low to mid-elevations and low to moderate moisture dominated by hardwood trees. Shrub and herb layers are similarly rich, and a mixture of flowering plants and ferns can be found along the forest floor with a variety of insects and other invertebrates roaming through them. The forest is typical of sheltered, shady places in the Blue Ridge and Appalachian Mountains, forming large patches (tens to hundreds of acres) on concave slopes that accumulate nutrients and moisture. The moisture-rich environment works to support several amphibian populations, including various frogs and toads. The lush vegetation and rocky outcrops also serve as home to a diverse population of snakes, including both venomous and non-venomous varieties. Turtles can also be found along the many streams that wind down the hilly slopes. Numerous insectivorous and herbivorous birds also call the forest habitat home, with many varieties of sparrows, warblers, and wrens being reported.

Although not as numerous, predatory birds, including eagles, falcons, hawks, owls and turkeys, can also be found within the forest. The vast majority of mammals are from lower trophic levels, with numerous bats, rabbits, mice, shrews and squirrels being reported. Predatory mammals include bears, bobcats, coyotes, foxes, raccoons, and weasels. As noted above, except for the larger predators, many of the animal species found in the Forest habitat have also been reported in the nearby prairies. In fact, approximately half of the species identified in the animal surveys were found in both the forest and prairie habitat areas.

Both of the specifically protected ecological areas identified within the study area, the Jefferson National Forest and Wildwood Park, are located within this habitat. In addition, many of the flowering plants that have been listed as endangered and the endangered bat species can be found within this habitat. Both the Henslow's sparrow and the hellbender salamander, both of which are reported as near threatened, are also present within this habitat. In addition, several flowering plans, insects and other soil invertebrates, and one species of wren that is identified as imperiled or critically imperiled can be found in the forest. Therefore, inclusion of this habitat in the SLERA, helps ensure protection of these endangered and threatened endangered species.

4.1.5.3 Freshwater Habitat

The Freshwater habitat is defined in this assessment as those areas classified as open water, ponds, swamps, marshes, and floodplain regions. It represents approximately 2 percent of the study area. The freshwater habitat includes main river channels and portions of lakes, ponds, and backwaters that remain permanently flooded all year and appear less than 10 percent vegetated. These freshwater areas and the adjacent riparian zones serve as home to a variety of plants and animals. Sedges and other plants that prefer moist soils can be found within the freshwater habitat, as can a variety of insects such as beetles, butterflies, flies, and moths. The aquatic crustaceans and mollusks, such as crayfish, mussels, and snails, serve as a ready food source for many of the animals within this habitat. As would be expected, many different amphibians can be found in the freshwater habitat, including toads, salamanders, and frogs. Reptiles, such as turtles and water snakes, can often be found basking on the edge of the waterbodies in this habitat. As with the other habitats, avian species include a combination of lower and higher trophic level species, such as the insectivorous woodcock, the herbivorous goose, and the predatory eagles, falcons, herons, and ospreys. The birds, as well as many of the mammals in the habitat, feed on the many fish species that are found here. Large fish such as bass, bluegills, catfish, darters, sculpin, and trout can be found throughout, as can a variety of feeder fish such as minnows and shiners. Mammals include bear, beavers and otters, lemmings, and raccoon.

The wetlands identified in the National Wetlands Inventory are included within the Freshwater habitat. In addition, Connelly's Run, as it flows through Wildwood Park, is included in this habitat. In addition to these special ecological areas, the endangered Roanoke logperch and the James spiny mussel can be found in this habitat. Several near-threatened darter fish and dragonflies and imperiled crustaceans are also found here. Therefore, inclusion of this habitat in the SLERA, helps ensure protection of these endangered and threatened endangered species.

4.1.6 Sensitive Ecological Communities

Several endangered, threatened, and imperiled species are distributed throughout the ecological habitats, with the most being found in the forested and freshwater areas, making these habitats of specific ecological importance. One identified species, *Neonympha mitchellii mitchellii*, is also found in prairie-like habitats, potentially classifying these habitats as having special ecological importance as well. In total, 27 different species were identified via a literature survey as either endangered, threatened, or imperiled in the area. Many of these species fall into the classification of an invertebrate or plant, which is not amenable to a food web type of risk analysis. However, the overall health of these species can be protected by comparing media concentrations to benchmarks for sustainability in a community-level analysis. For those few species that are amenable to a food web analysis, they have been considered when establishing measurement receptors for each food web analysis and will be protected via the food web portion of the SLERA.

In addition to the endangered, threatened, and imperiled species that were identified in the study area, two specifically protected ecological areas were also identified. These include:

- The Jefferson National Forest (JNF) – The JNF is a forested region located to the north and west of the EWI operations, away from the prevailing wind direction. The JNF is, according to the Virginia State parks, home to some of the highest populations of wild turkey, white-tail deer, black bear, squirrel, and ruffed grouse. The JNF also provides excellent fishing opportunities for both native and stocked trout, bass, bluegill, and channel catfish. The receptor grid provided for this assessment covers the entire breadth of the JNF within the assessment area.
- Wildwood Park – Wildwood Park is located in the City of Radford, south and west of the EWI operations, away from the prevailing wind direction. Wildwood Park is a city greenway provided for

nature studies and community recreation. The primary ecological feature within the park is Connelly's Run, which runs through the center of the surrounding wooded area. Both Wildwood Park and Connelly's Run are covered by the receptor grid provided for this assessment.

In addition, most of the small tributaries stemming from the major creeks and streams are identified as wetlands in the National Wetland inventory.

As discussed previously, the overall health of these sensitive ecological areas is protected by the inclusion of the habitats discussed in Section 4.1.5.

4.2 HUMAN HEALTH EXPOSURE SCENARIOS

An exposure scenario is a combination of exposure pathways to which a single receptor may be subjected. An exposure pathway is the means by which a constituent moves from a source to a receptor. A completed exposure pathway has the following four elements:

- A constituent source and mechanism for release of the constituent;
- An environmental transport medium;
- A feasible route of potential exposure; and
- A specific point of exposure with an identified receptor.

The focus of the MPRA was to evaluate the potential effects that the EWI emissions could have on the health of humans residing and working offsite within the assessment area. In this respect two main groups of receptors were identified: general members of the population residing, farming, and fishing in the local community and special groups of receptors that may be more susceptible to the effects from EWI emissions.

4.2.1 GENERIC RECEPTORS

Four general types of human health receptors were evaluated in the MPRA:

- Adult and children residents living at the maximum impacted offsite location(s) that could allow a domicile to be established. This could include any forested area, agricultural area, or urban area within the assessment area.
- Adult and children subsistence fishers residing at the maximum impacted offsite location(s) that could allow a domicile to be established and fishing surface waterbodies with the highest modeled fish tissue concentrations in the assessment area.
- Adult and children subsistence farmers residing at the maximum impacted offsite location(s) of agricultural land use or potential agricultural land use and subsisting off of homegrown produce and animal products grown and raised at this location.
- Adult and children acute receptors spending at least one hour at the offsite location with the highest hourly air concentrations.

Based upon a review of the land use and population demographics for the assessment area, it is highly unlikely that any subsistence farmers or fishers actually reside in the area. However, these exposure scenarios were included to provide reasonable maximum exposure (RME) estimates for the risk calculations.

The location at which each of these receptors were assessed was determined by superimposing the deposition and concentration model outputs onto topographic and land use maps. Combined, this data was used to select receptor locations that represent the RME to each type of offsite receptor. Three separate locations were identified. Two of these were identified as RME locations for the resident, subsistence fisher, and subsistence farmer scenarios:

- Location A is found west-northwest of the EWIs at 539,200E, 4,117,400N. This location is on existing farmland across the New River from the EWIs. This location provides adequate space for both a residence and a farm.
- Location B is also west-northwest of the EWIs, with map coordinates of 539,300E, 4,117,400N. This location is on existing farmland across the New River from the EWIs and, like Location A, provides adequate space for both a residence and a farm.

One location was identified as the RME for the acute exposure assessment. This location, referred to as Location C, is located at 539,600E, 4,117,500N, north-northwest of the EWIs. The area at this receptor point is across the New River from the EWIs, is wooded, and represents a location at which an individual could spend an hour of their time hiking, hunting, *etc.*

The modeling results for each of the locations is summarized in Table 4-4 below and is detailed in Tables A-1.1 through A-1.3 in Appendix A.

TABLE 4-4
RECEPTOR LOCATIONS AND MODELING RESULTS FOR THE MPRA (UNITY BASIS)

MODELING RESULT		UNITS	RESIDENT, FISHER, FARMER EXPOSURE SCENARIOS		ACUTE EXPOSURE
			539,200 E, 4,117,400N (LOCATION A)	**539,300E, 4,117,400N (LOCATION B)**	**539,600E, 4,117,500N (LOCATION C)**
Cyv	Unitized yearly average air concentration from vapor phase	$\mu g \cdot s/g \cdot m^3$	1.73	1.68	NA
Cyp	Unitized yearly air concentration from particle phase	$\mu g \cdot s/g \cdot m^3$	1.72	1.70	NA
Cyp	Unitized yearly air concentration from particle bound	$\mu g \cdot s/g \cdot m^3$	1.72	1.68	NA
Chv	Unitized hourly air concentration from vapor phase	$\mu g \cdot s/g \cdot m^3$	NA [1]	NA	114

TABLE 4-4 (CONTINUED)
RECEPTOR LOCATIONS AND MODELING RESULTS FOR THE MPRA (UNITY BASIS)

MODELING RESULT		UNITS	RESIDENT, FISHER, FARMER EXPOSURE SCENARIOS		ACUTE EXPOSURE
			539,200 E, 4,117,400N	539,300E, 4,117,400N	539,600E, 4,117,500N
Chp	Unitized hourly air concentration from particle phase	µg·s/g·m³	NA	NA	112
Chpb	Unitized hourly air concentration from particle bound	µg·s/g·m³	NA	NA	113
Dydv	Unitized yearly average dry deposition from vapor phase	s/m²·yr	0.000234	0.000254	NA
Dydp	Unitized yearly average dry deposition from particle phase	s/m²·yr	0.0703	0.0803	NA
Dydp	Unitized yearly average dry deposition from particle bound	s/m²·yr	0.00976	0.0106	NA
Dywp	Unitized yearly average wet deposition from particle phase	s/m²·yr	0.00903	0.00934	NA
Dywp	Unitized yearly average wet deposition from particle bound	s/m²·yr	0.000336	0.000346	NA

1 Not applicable. The specified modeling result is not used for the specified assessment.

4.2.2 SPECIAL SUBPOPULATIONS

As discussed previously, several types of subpopulations were also assessed in the MPRA. These included:

- Children and teachers at the most impacted school and day care center;
- Elderly residents at the most impacted nursing home; and
- Child and adult patients at the most impacted hospital.

Of the many special subpopulations identified within the assessment area, those that had the highest overall modeling results were included in the risk calculations. Maxima results were spread across several different locations for each subpopulation type. For example, two nursing homes had the highest overall modeling results:

- Community Assisted Living in Christiansburg had the highest overall annual average air concentrations and deposition rates; and

➢ Community Assisted Living in Radford had the highest overall hourly air concentrations.

For each of the different types of special subpopulations, a theoretical "worst-case" subpopulation was created that represented the combined highest modeling values between all of the special subpopulations in a specific type. The resulting air modeling results for each location are summarized in Table 4-5 below and are detailed in Tables A-1.4 through A-1.7 in Appendix A.

TABLE 4-5
PROPOSED SPECIAL SUBPOPULATION LOCATIONS AND MODELING RESULTS FOR THE MPRA (UNITY BASIS) [1]

Modeling Result		Units	Elementary School [2]	Daycare [3]	Nursing Home [4]	Hospital
Cyv	Unitized yearly average air concentration from vapor phase	µg·s/g·m³	0.0857	0.0630	0.0585	0.0387
Cyp	Unitized yearly air concentration from particle phase	µg·s/g·m³	0.0838	0.0601	0.0558	0.0369
Cyp	Unitized yearly air concentration from particle bound	µg·s/g·m³	0.0853	0.0625	0.0581	0.0384
Chv	Unitized hourly air concentration from vapor phase	µg·s/g·m³	10.9	9.73	6.68	3.28
Chp	Unitized hourly air concentration from particle phase	µg·s/g·m³	10.8	9.59	6.53	3.17
Chpb	Unitized hourly air concentration from particle bound	µg·s/g·m³	10.8	3.14	6.63	3.25
Dydv	Unitized yearly average dry deposition from vapor phase	s/m²·yr	0.000016	0.000010	0.000010	0.000010
Dydp	Unitized yearly average dry deposition from particle phase	s/m²·yr	0.00367	0.00317	0.00296	0.00176
Dydp	Unitized yearly average dry deposition from particle bound	s/m²·yr	0.000606	0.000468	0.000440	0.000314
Dywp	Unitized yearly average wet deposition from particle phase	s/m²·yr	0.000246	0.000108	0.000068	0.000072
Dywp	Unitized yearly average wet deposition from particle bound	s/m²·yr	0.000010	0.000006	0.000004	0.000002

1 As explained in the text, several locations were combined to reflect a theoretical worst-case location for each of the four special subpopulations.

2 The theoretical elementary school location represents a combination of modeling results from Belview Elementary, Prices Fork Elementary, and Riverlawn Elementary. The highest annual average modeling results were modeled at Belview and Prices Fork Elementary Schools. The highest hourly average modeling results were modeled at Riverlawn Elementary School.

3 The theoretical day care location represents a combination of modeling results from Cedarwood Preschool, St. Mary's Angels, and New River Community Action Center. The highest annual average modeling results were modeled at Cedwarwood Preschool and St. Mary's Angels. The highest hourly average modeling results were modeled at New River Community Action Center.

4 The theoretical nursing home location represents a combination of modeling results from Community Assisted Living in Christiansburg and Community Assisted Living in Radford. The highest annual average modeling results were modeled at the Christiansburg location, and the highest hourly average modeling results were modeled at the Radford location.

4.2.3 WATERBODIES

Air modeling data for each of the four studied waterbodies is used in three ways in the MPRA: in the assessment of risk due to drinking water ingestion, in the assessment of risk to the subsistence fisher from the consumption of fish living in the waterbodies, and in the assessment of ecological risk. The air modeling results for each waterbody are summarized in Table 4-6 and are detailed in Table A-2 of Appendix A. The values provided represent the average values measured across all of the receptors associated with a given waterbody.

TABLE 4-6
WATERBODY MODELING RESULTS FOR THE MPRA (UNITY BASIS)

WATERBODY	NO. OF RECEPTORS	ANNUAL VAPOR AIR CONCENTRATION	ANNUAL TOTAL DEPOSITION (VAPOR PHASE)	ANNUAL TOTAL DEPOSITION (PARTICLE PHASE)	ANNUAL TOTAL DEPOSITION (PARTICLE BOUND)
		Cywv	Dytwv	Dytwp	Dytwp
Back Creek	48	0.1202	0.0000141	0.00482	0.000682
Lick Run	45	0.0758	0.0000116	0.00369	0.000525
Little River	5	0.1043	0.0000124	0.00781	0.000816
New River	970	0.1612	0.0000256	0.01113	0.001346

4.3 ECOLOGICAL EXPOSURE SCENARIOS

For the SLERA, two different ecological assessment endpoints were established to provide direct evaluation of the impact to selected measurement receptors. These include

- Community Receptors - For lower trophic level species and species without adequate ecological nutritional data, the assessment endpoint will be the relative health of environmental media to TRVs for that media. For example, for terrestrial plants identified in the ecological communities, the SLERA will compare the modeled COPC concentrations in the soil to soil TRVs that have been determined to be protective of terrestrial plants. For waterbodies, a comparison to the Federal and State water quality standards will also be made.
- Food Web Receptors - For higher trophic level species that have adequate ecological nutritional data, the assessment endpoint will be a direct measure of the modeled ingested does of each COPC to an ingestion-based TRV for the measurement receptor. These comparisons will serve as an indirect measure of impacts to other species within the same family of guild for which that measurement receptor is representative.

The assessment of ecological risk to each of these sets of receptors was performed at the location of maximum impact within the assessment area. While two separate locations were assessed for the HHRA, only one location was assessed for the SLERA. This location represented the combination of the highest air modeling values from Locations A and B provided earlier in Table 4-5. The waterbody modeling results for the MPRA were provided previously in Table 4-6.

4.3.1 COMMUNITY RECEPTORS

For the lower trophic levels and those guilds that do not have nutritional data available (*e.g.,* fish and reptiles), the exposure scenario is focused on the entire ecological community or collection of communities and no specific species are selected. Tables 4-7 and 4-8 identify the community receptors there were selected for this exposure scenario. Further information about the reasoning behind these selections, including the critical ecological attributes for each was provided in the MPRA Protocol for the open burning grounds (RFAAP, 2019b). For each of the community receptors the relative impact of emissions was assessed by comparing modeled concentrations in the respective media to TRVs and water quality standards for that community.

TABLE 4-7
COMMUNITY RECEPTORS FOR THE PRAIRIE AND FOREST FOOD WEB

COMMUNITY OR GUILD	TROPHIC LEVEL	PRIMARY SPECIES		COMMUNITY MEASUREMENT RECEPTOR
		FOREST	PRAIRIE	
Terrestrial Plants	1	Sedges, Rushes, Coneflowers	Oaks, Asters, Grasses	Terrestrial Plants
Invertebrates and Other Herbivorous Invertebrates	2	Butterflies, Snails, Moths		Soil invertebrates

TABLE 4-8
COMMUNITY RECEPTORS FOR THE FRESHWATER FOOD WEB

COMMUNITY OR GUILD	TROPHIC LEVEL	PRIMARY SPECIES	COMMUNITY MEASUREMENT RECEPTOR
Aquatic and Terrestrial Plants	1	Sedges, Goldenrods, Bluets	Terrestrial plants
Phytoplankton		Algae	Fresh water
Benthic Invertebrates	2	Crayfishes, Snails, Mussels	Freshwater sediment
Insects and Other Herbivorous Invertebrates		Butterflies, Moths, Caddisflies	Soil invertebrates
Herbivorous Fish		Stonerollers	Fresh water
Insectivorous Fish	3	Darters, Minnows, Bass	Fresh water
Omnivorous Fish		Shiners, Madtoms, Bullheads	Fresh water
Carnivorous Fish	4	Bowfins, Walleyes, Muskellunges	Fresh water

4.3.2 Food Web Receptors

For the higher trophic levels, food web exposure scenarios were established for each habitat to model the COPC dose ingested by each class-specific guild and to determine a whole body COPC concentration found in prey eaten by predators. Food web receptors were selected using four main criteria:

- Ecological relevance
- Exposure potential and sensitivity
- Social or economic importance
- Availability of natural history information

The selected food web receptors are representative of other species in the guild and provide a baseline to ensure that all receptors in the guild are protected. This baseline shows that if the risk to the measurement receptor is acceptable, the risk to all other species in the guild would also be acceptable. The resulting receptors for the food web exposure scenarios are presented in Tables 4-9 and 4-10. Simplified models of the food web scenarios for each of the two habitats are provided in Figures 4-1 and 4-2. Further information about the reasoning behind these selections, including the critical ecological attributes for each was provided in the MPRA Protocol for the open burning grounds (RFAAP, 2019b).

Table 4-9
Food Web Receptors – Combined Prairie/Forest Habitat

Community or Guild	Trophic Level	Primary Species: Forest	Primary Species: Prairie	Measurement Receptor
Herbivorous birds	2	Waxwings, Towhees, Grosbeaks, Bobwhites		Northern bobwhite
		Crossbills, Finches	Bobolinks, Doves	
Herbivorous mammals		Squirrels, Deer, Rabbits, Voles		Meadow vole
Insectivorous birds	3	Warblers, Sparrows		American woodcock
		Woodpeckers, Wrens	Swallows, Flycatchers	
Insectivorous mammals		Mice, Bats, Shrews		Short-tailed shrew
		Opossums, Skunks	Muskrats	
Omnivorous birds		Turkeys, Thrashers, Robins		American robin
		Mockingbirds	Cowbirds	
Omnivorous mammals		Bears, Raccoons		Raccoon
Carnivorous birds	4	Falcons, Vultures, Hawks, Owls		Red-tailed hawk
Carnivorous mammals		Foxes, Minks, Weasels		Red fox

Table 4-10
Food Web Receptors – Freshwater Habitat

Community or Guild	Trophic Level	Primary Species	Measurement Receptor
Herbivorous birds	2	Geese, Coots, Waxwings	Canada goose
Herbivorous mammals		Moles, Chipmunks, Rabbits, Lemmings, Beavers	Meadow vole
Insectivorous birds	3	Flycatchers, Sandpipers, Phalaropes	American woodcock
Insectivorous mammals		Mice, Shrews, Muskrats	Short-tailed shrew
Omnivorous birds		Kingbirds, Mallards, Ducks, Gulls, Teals	Mallard
Omnivorous mammals		Bears, Raccoons	Raccoon
Carnivorous mammals	4	Minks	Red fox
Carnivorous shore birds		Herons, Cormorants, Grebes	Great blue heron

FIGURE 4-1
SIMPLIFIED FOOD WEB MODEL FOR THE PRAIRIE/FOREST FOOD WEB

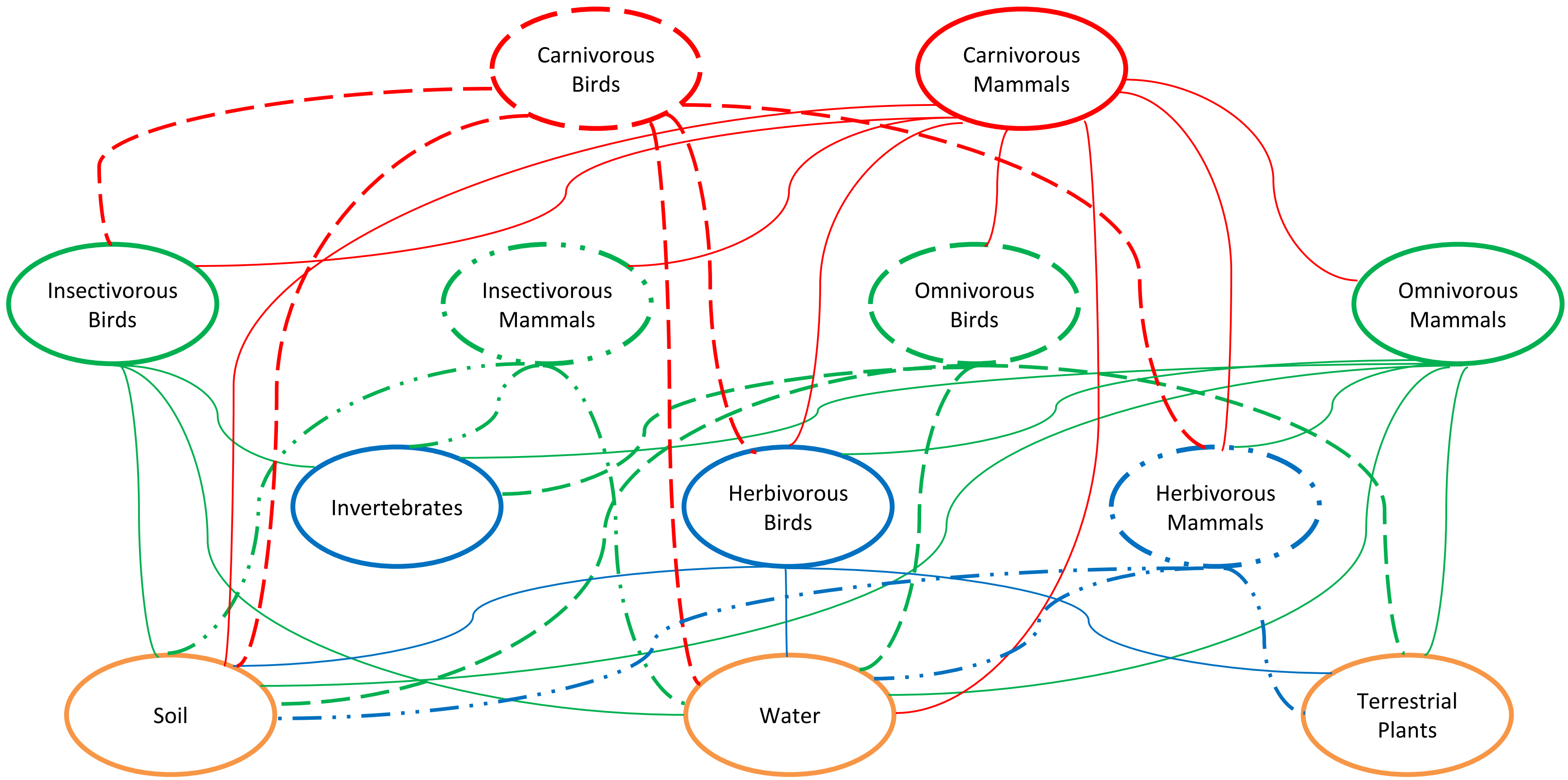
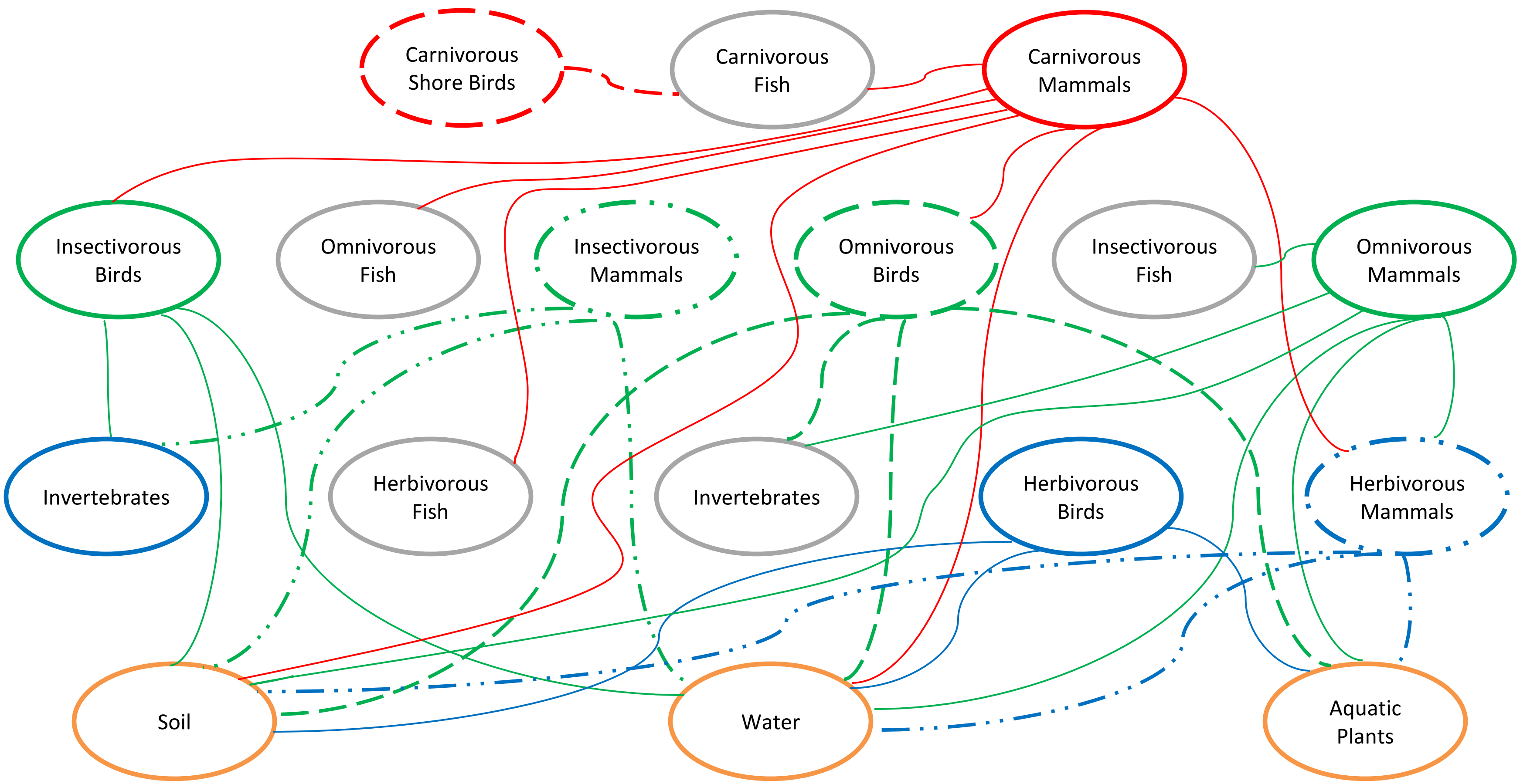


FIGURE 4-2
SIMPLIFIED FOOD WEB MODEL FOR THE FRESHWATER FOOD WEB



5.0 HUMAN HEALTH EXPOSURE ASSESSMENT

The air modeling described in Section 3 generated a range of modeled COPC concentrations from the EWIs based on the RME for both ambient air concentrations and deposition rates. These COPC concentrations were used to determine the exposure, or average daily chemical intake, at each receptor.

Average daily intake (ADI) is exposure expressed as the mass of a substance contacted per unit body weight per unit time, averaged over a period of years. The ADIs for COPCs at selected receptor locations were calculated using the exposure equations and, where applicable, the assumptions summarized in the MPRA Protocol (RFAAP, 2019b) and detailed in the HHRAP, Volume Three (USEPA, 2005). For non-carcinogenic exposures, the intake is referred to as an average daily dose (ADD); for carcinogenic exposures, the intake is referred to as the lifetime average daily dose (LADD). The general formula for calculating intake is:

$$I = \frac{C_{GEN} \times CR \times EF \times ED}{BW \times AT}$$

Where: -

I	=	Intake (either ADD or LADD), expressed in amount/kg body weight/day
CGEN	=	COPC concentration in media of concern (i.e., mg/kg in soil)
CR	=	Consumption rate, expressed in amount per day
EF	=	Exposure frequency, expressed in days per year
ED	=	Exposure duration, expressed in years
BW	=	Average body weight of receptor, expressed in kilograms
AT	=	Averaging time, expressed in days

The following sections provide more detail on how the media concentrations were determined and combined with assumptions for intake to arrive at the ADD and LADD for each selected receptor.

5.1 HUMAN HEALTH ASSESSMENT INPUT DATA

The input criteria utilized for each of the human health exposure scenarios are provided along with the air modeling results for each location in Appendix A. The input data within the appendix is organized as follows:

- Table A-3 provides the COPC emission rates that were utilized in the HHRA and SLERA evaluations.
- Table A-4 provides the waterbody input parameters, such as watershed area, water body temperature, *etc.*, that were used in the HHRA and SLERA evaluations.

- Table A-5 provides the constants utilized for the receptors in the HHRA evaluation.
- Table A-6 provides the constants utilized for the waterbody calculations in the HHRA evaluation.
- Table A-7 provides the site-specific variables utilized for the receptors in the HHRA evaluation.
- Table A-8 provides the site-specific variables utilized for the waterbody calculations in the HHRA evaluation.
- Table A-9 provides the constituent transport criteria for each of the COPCs that were used in the COPC fate and transport assessment.
- Table A-10 provides the constituent transport criteria for each of the COPCs that were used in the assessment of COPC fate and transport assessment in the waterbodies.

5.2 COPC Concentrations in Environmental Media

The concentration of each COPC in environmental media was determined from the deposition rates and air concentrations predicted by the OBODM model. For this MPRA, concentrations of COPCs were calculated for various media, including the ambient air, soil, water, sediment, produce, and animal products. The COPC concentrations in environmental media for each of the assessed exposure scenarios is provided in Appendix B. The data within the appendix is organized as follows:

- Tables B-1.1 through B-1.4 provide the COPC loss constants calculated for each exposure scenario in the HHRA. Note that soil loss constants are only provided for those exposure scenarios that included the incidental ingestion of soil.
- Tables B-2.1 through B-2.4 provide the COPC soil concentrations calculated for each exposure scenario in the HHRA. Note that soil concentrations are only provided for those exposure scenarios that included the incidental ingestion of soil.
- Tables B-3.1 through B-3.7 provide the COPC air concentrations calculated for each exposure scenario in the HHRA.
- Tables B-4.1 through B-4.4 provide the COPC produce concentrations calculated for each exposure scenario in the HHRA. Note that produce concentrations are only provided for those exposure scenarios that included the ingestion of homegrown produce.
- Tables B-5.1 and B-5.2 provide the COPC animal concentrations calculated for each subsistence famer exposure scenario in the HHRA. Note that animal concentrations are only provided for those exposure scenarios that included the ingestion of homegrown animal products.
- Table B-6 provides the COPC fish concentrations calculated for each waterbody. These fish concentrations were only included in the subsistence fisher scenario and were the same for both locations, as the location at which the fisher fishes is the same regardless of where the fisher is assumed to reside.
- Table B-7 provides the COPC drinking water concentrations calculated for the New River, which is used as a drinking water source for the local community. Drinking water ingestion was included for each of the general receptors.
- Table B-8 provides the COPC soil concentrations calculated for each of the assessed waterbodies.
- Table B-9 provides the direct deposition load of each COPC calculated for each of the assessed waterbodies.

- Table B-10 provides the impervious runoff load of each COPC calculated for each of the assessed waterbodies.
- Table B-11 provides the pervious runoff load of each COPC calculated for each of the assessed waterbodies.
- Table B-12 provides the soil erosion load of each COPC calculated for each of the assessed waterbodies.
- Table B-13 provides the diffusion load of each COPC calculated for each of the assessed waterbodies.
- Table B-14 provides the total COPC load calculated for each waterbody.
- Table B-15 provides the COPC sediment concentrations calculated for each of the assessed waterbodies.
- Table B-16 provides the COPC dissolved-phase concentrations calculated for each of the assessed waterbodies.
- Table B-17 provides the COPC water column concentrations calculated for each of the assessed waterbodies.
- Table B-18 provides the COPC dissipation rate constants calculated for each of the assessed waterbodies.
- Table B-19 provides the total COPC water concentrations calculated for each of the assessed waterbodies.

5.2.1 Soil Concentrations

COPC concentrations in soil were calculated from the COPC deposition rates determined via air modeling. The calculated soil concentrations were averaged over the exposure period in order to quantify risk for incidental soil ingestion and consumption of homegrown food. The equations for the determination of soil concentration from deposition rates were obtained from Volume Three of the HHRAP (USEPA, 2005). The calculation assumes the following:

- Only a thin layer of soil becomes contaminated;
- This layer can be assumed to be either "tilled" – mixed to 20 centimeters, or "untilled" – mixed to one centimeter; and
- Soil residues are assumed to dissipate at a rate related to the combined effects of degradation, erosion, runoff, leaching, and volatilization.

As recommended in the HHRAP, a mixing depth of one centimeter was used for all calculations involving non-tilled land (i.e. incidental soil ingestion and animal product concentrations). A mixing depth of 20 centimeters was used for calculations involving tilled land (i.e. produce, forage, silage and grain uptake). For calculations dealing with surface water runoff, a mixing depth of one centimeter was used.

Tables B-1.1 through B-1.4 provide the COPC loss constants calculated for each of the assessed exposure scenarios as follows:

- Table B-1.1 presents the soil loss constants for each COPC calculated for the resident, fisher, and farmer receptors found at Location A.
- Table B-1.2 presents the soil loss constants for each COPC calculated for the resident, fisher, and farmer receptors found at Location B.
- Table B-1.3 presents the soil loss constants for each COPC calculated for the elementary school scenario.
- Table B-1.4 presents the soil loss constants for each COPC calculated for the daycare scenario.

These soil loss constants are then used to determine the predicted COPC soil concentrations at each of the assessed exposure scenarios. These soil concentrations are presented in Tables B-2.1 through B-2.4., as follows:

- Table B-2.1 presents the soil concentrations of each COPC calculated for the resident, fisher, and farmer receptors found at Location A.
- Table B-2.2 presents the soil concentrations of each COPC calculated for the resident, fisher, and farmer receptors found at Location B.
- Table B-2.3 presents the soil concentrations of each COPC calculated for the elementary school scenario.
- Table B-2.4 presents the soil concentrations of each COPC calculated for the daycare scenario.

5.2.2 AIR CONCENTRATIONS

For each modeling location, the air dispersion model provided the ambient air concentration of vapor and particulate-phase COPCs. These were normalized to reflect actual facility operations and were then unitized to provide emissions on a 1 gram per second (g/s) basis as described in Section 3. The following equation was used to estimate air concentrations of COPCs at each modeling location using the air modeling outputs and the emission factors described in Section 3. These air concentrations were used directly in the calculation of inhalation intake.

$$C_a = Q \times \left[F_v \times Cyv + \left(1 - F_v\right) \times Cyp\right]$$

Where:

Ca	=	concentration of COPC in air ($\mu g/m^3$)
Q	=	COPC emission rate (g/s), determined by multiplying the EF (lb COPC/lb NEW) by the amount (lb) of material burned
Fv	=	fraction of COPC in vapor phase (unitless)
Cyv	=	model output vapor phase concentration ($\mu g/m^3$)
Cyp	=	model output particle phase concentration ($\mu g/m^3$)

The air concentrations of COPC for each of the exposure scenarios are presented in Tables B-3.1 through B-3.7, as follows:

- Table B-3.1 provides the air concentrations calculated for the resident, fisher, and farmer receptors found at Location A.
- Table B-3.2 provides the air concentrations calculated for the resident, fisher, and farmer receptors found at Location B.
- Table B-3.3 provides the hourly air concentrations calculated for the acute receptor found at Location C.
- Table B-3.4 provides the air concentrations calculated for the elementary school scenario.
- Table B-3.5 provides the air concentrations calculated for the daycare scenario.
- Table B-3.6 provides the air concentrations calculated for the nursing home scenario.
- Table B-3.7 provides the air concentrations calculated for the hospital scenario.

5.2.3 PRODUCE CONCENTRATIONS

The air dispersion model provided air concentration and deposition rate values for each receptor node. These values were converted to aboveground exposed produce concentration due to direct deposition, aboveground exposed produce concentration due to air-to-plant transfer, aboveground exposed and protected produce concentration due to root uptake, and below ground produce concentration due to root uptake. The equations for this conversion were obtained from HHRAP, Volume Three (USEPA, 2005). For each exposure scenario involving ingestion of homegrown produce, soil concentrations were calculated assuming a mixing depth of 20 centimeters.

Consumption of homegrown produce was only included in the generic resident, fisher, and farmer exposure scenarios. The produce concentrations calculated for each COPC in these exposure scenarios are presented in Tables B-4.1 through B-4.4, as follows:

- Table B-4.1 presents the produce concentrations of each COPC calculated for the resident and fisher found at Location A.
- Table B-4.2 presents the produce concentrations of each COPC calculated for the farmer found at Location A.
- Table B-4.3 presents the produce concentrations of each COPC calculated for the resident and fisher found at Location B.
- Table B-4.4 presents the produce concentrations of each COPC calculated for the farmer found at Location B.

5.2.4 ANIMAL PRODUCT AND FISH CONCENTRATIONS

The air dispersion model provided air concentration and deposition rate values for each receptor node. These values were first converted to silage, forage, and grain concentrations. Then animal product concentrations were calculated based on animal ingestion of silage, forage, grain, and soil. Animal products include beef, milk, poultry, eggs, and pork. The equations for this conversion were obtained from HHRAP, Volume Three (USEPA, 2005).

Consumption of homegrown animal products was only included in the generic farmer exposure scenario. The animal produce concentrations calculated for each COPC at Location A and Location B are provided in Tables B-5.1 and B-5.2, respectively.

Fish concentrations were determined for each of the evaluated surface waterbodies using the calculated total water column and sediment concentrations. The total water column and sediment concentrations were determined as described previously. The calculated fish concentrations for each COPC were then determined using the equations provided in the HHRAP, Volume Three. The calculated fish concentrations used in the subsistence fisher scenario are provided in Table B-6.

5.2.5 WATER AND SEDIMENT CONCENTRATIONS

As discussed previously, the air dispersion model provided COPC deposition rates in terms of grams per square meter per year per gram per second of material burned ((g/m^2/yr)/(g/s)). Deposition rates were converted to total water column and sediment concentrations averaged over the exposure period in order to quantify risk for fish consumption and drinking water ingestion. The equations for this conversion were obtained from the HHRAP, Volume Three (USEPA, 2005). The equations distribute deposition on the surface of the waterbody and on soil in the drainage basin to the waterbody, to the water column, and to the upper benthic sediment layer.

Drinking water is supplied from the New River to the surrounding community. The ingestion of surface-supplied drinking water was included for each of the general exposure scenarios. Drinking water concentrations, which are presented in Table B-7, were used in the assessment of risk for each of the general exposure scenarios.

Arriving at the actual COPC concentration in each waterbody includes a series of calculations that begin by calculating the COPC soil concentrations for the area surrounding each waterbody and the associated direct deposition, impervious, pervious, soil erosion, and diffusion loads into each waterbody. The resultant total waterbody load for each COPC is then used to determine the actual concentration of each COPC in each waterbody. The following tables in Appendix B document the load calculations and results:

- Table B-8 provides the COPC soil concentrations calculated for each of the assessed waterbodies.
- Table B-9 provides the direct deposition load of each COPC calculated for each of the assessed waterbodies.
- Table B-10 provides the impervious runoff load of each COPC calculated for each of the assessed waterbodies.
- Table B-11 provides the pervious runoff load of each COPC calculated for each of the assessed waterbodies.
- Table B-12 provides the soil erosion load of each COPC calculated for each of the assessed waterbodies.

- Table B-13 provides the diffusion load of each COPC calculated for each of the assessed waterbodies.
- Table B-14 provides the total COPC load calculated for each waterbody.

Once the total load has been determined, COPC waterbody sediment concentration, dissolved-phase concentration, and water column concentration are employed with COPC dissipation rate constants to determine the total concentration of COPC in each waterbody. The following tables in Appendix B document this process:

- Table B-15 provides the COPC sediment concentrations calculated for each of the assessed waterbodies.
- Table B-16 provides the COPC dissolved-phase concentrations calculated for each of the assessed waterbodies.
- Table B-17 provides the COPC water column concentrations calculated for each of the assessed waterbodies.
- Table B-18 provides the COPC dissipation rate constants calculated for each of the assessed waterbodies.
- Table B-19 provides the total COPC water concentrations calculated for each of the assessed waterbodies.

5.3 EXPOSURE RATES

Exposure rates, such as inhalation rates for air and consumption rates for soil, produce, animal products, fish, and drinking water, determine the amount of COPC to which each receptor is exposed through the indirect pathway. Lower consumption rates of contaminated materials will result in lower exposure to the receptor. The following sections provide descriptions of the consumption rates employed in this MPRA. Table 5-1 provides a summary of the exposure rates used for each of the assessed scenarios. Further discussion on the basis for these rates is provided in the sections that follow.

Table 5-1
Exposure Rates for Targeted Human Health Receptors

Receptor	Inhalation (m^3/hr) [1]	Soil Ingestion (kg/day) [1]	Food Consumption (kg/kg-BW-day) [1]	Drinking Water Consumption (L/Day) [2]	Skin Absorption (mg/cm^2/event) [3]
Farmer	Adult: 0.83 Child: 0.30	Adult: 0.0001 Child: 0.0002	Adult: $Produce_{AGE}$: 0.00047 $Produce_{AGP}$: 0.00064 $Produce_{BG}$: 0.00017 Beef: 0.00122 Milk: 0.01367 Pork: 0.00055 Poultry: 0.00066 Eggs: 0.00075 Child: $Produce_{AGE}$: 0.00113 $Produce_{AGP}$: 0.00157 $Produce_{BG}$: 0.00028 Beef: 0.00075 Milk: 0.02268 Pork: 0.00042 Poultry: 0.00045 Eggs: 0.00054	Adult: 2.5 Child: 0.78	Adult: 0.07 Child: 0.20
Fisher	Adult: 0.83 Child: 0.30	Adult: 0.0001 Child: 0.0002	Adult: $Produce_{AGE}$: 0.00032 $Produce_{AGP}$: 0.00061 $Produce_{BG}$: 0.00014 Fish: 0.00125 Child: $Produce_{AGE}$: 0.00077 $Produce_{AGP}$: 0.0015 $Produce_{BG}$: 0.00023 Fish: 0.00088	Adult: 2.5 Child: 0.78	Adult: 0.07 Child: 0.20
Resident	Adult: 0.83 Child: 0.30	Adult: 0.0001 Child: 0.0002	Adult: $Produce_{AGE}$: 0.00032 $Produce_{AGP}$: 0.00061 $Produce_{BG}$: 0.00014 Child: $Produce_{AGE}$: 0.00077 $Produce_{AGP}$: 0.0015 $Produce_{BG}$: 0.00023	Adult: 2.5 Child: 0.78	Adult: 0.07 Child: 0.20

Table 5-1 (continued)
Exposure Rates for Targeted Human Health Receptors

Receptor	Inhalation (m^3/hr)	Soil Ingestion (kg/day)	Food Consumption (kg/kg-BW-day)	Drinking Water Consumption (L/Day)	Skin Absorption (mg/cm^2/event)
Daycare centers	Adult: 0.83 Child: 0.30	Adult: 0.0001 Child: 0.0002	N/A	N/A	N/A
Elementary schools	Adult: 0.83 Child: 0.30	Adult: 0.0001 Child: 0.0001	N/A	N/A	N/A
Nursing home	Adult: 0.83	N/A	N/A	N/A	N/A
Hospital	Adult: 0.83 Child: 0.30	N/A	N/A	N/A	N/A
Acute risk	Adult: 0.83 Child: 0.30	N/A	N/A	N/A	N/A

1 As specified in the final HHRAP (USEPA, 2005).
2 As specified in USEPA's Exposure Factor's Handbook (USEPA, 2011).
3 As specified in the USEPA's Risk Assessment Guidance for Superfund (USEPA 2004).

5.3.1 Inhalation Rate

Air concentrations calculated from the air dispersion model are used directly in the calculation of inhalation intake. The breathing rate was varied with the age of the receptor in each exposure scenario. For all adult receptors, the HHRAP default inhalation rate of 0.83 cubic meters per hour (m^3/hr) was used. For child and student receptors, an inhalation rate of 0.30 m^3/hr was used. Direct inhalation of COPCs was included in all exposure scenarios.

5.3.2 Soil Consumption Rate

Exposure to constituents in soil occurs by direct, inadvertent ingestion of soil. The quantity of incidental ingestion varies with the age of the receptor in each exposure scenario. For all adult receptors, the HHRAP default soil consumption rate of 0.0001 kilograms per day (kg/day) was used. For child and student receptors, a soil consumption rate of 0.0002 to 0.0001 kg/day was used as requested by VDEQ. The very small difference (0.0002 kg/day for daycare and non-school aged children versus 0.0001 kg/day for elementary school children) reflects a slight increased rate for daycare and non-school age children to mouth objects and suck on their hands and fingers more than those of school-aged children. Incidental soil ingestion of COPCs was included for the farmer, fisher, and resident, as well as for the workers and students in the elementary school and day care exposure scenarios.

5.3.3 Food Consumption Rates

The food consumed and the rate of consumption varies with exposure scenario. Additionally, the consumption of homegrown or locally caught food was not included in every exposure scenario. Ingestion of homegrown or locally caught food was only included in the three general exposure scenarios. Workers and students at the school and the day care center do not ingest any COPC contaminated food grown at the exposure location; neither due residents of the nursing home or patients at the hospital.

For the farmer and farmer child scenarios, it was assumed that 100 percent of the produce consumed is contaminated and that 100 percent of the tissues from the consumed beef, milk, pork, poultry, and eggs is contaminated. Default distributions for the relative amounts of homegrown fruits, vegetables, beef, pork, poultry, eggs, and milk consumed by the farmer and farmer child were used in the MPRA. No modifications to these distributions were made based on local farming trends or consumption habits.

For the fisher and fisher child scenarios, it was assumed that only 25 percent of the produce consumed by the fisher and fisher child is homegrown at the exposure location and that the overall consumption rates of produce are slightly less than those associated with the farming scenario. In addition, it is assumed that 100 percent of the fish consumed is contaminated. The fisher and fisher child are the only receptors that included fish consumption as an exposure pathway. Conservative default values for consumed fish were used in all calculations. No modifications to fish type or consumption rates were varied based on local trends.

For the adult and child resident scenarios, it was assumed that the only contaminated food consumed was from homegrown produce. Considering that the resident scenario is not based on the resident subsisting off of the homegrown produce, it was assumed that only 25 percent of the produce consumed is homegrown and consequently contaminated. In addition, since the resident is not subsiding off of this produce, the consumption rates utilized for those were slightly less than those associated with the farming scenario.

5.3.4 DRINKING WATER CONSUMPTION RATES

Surface water from the New River is the source of drinking water for many residents in the vicinity of the RFAAP. A study of water use in the area indicated that the majority of the population relies on a public supply of drinking water from surface waterbodies. Therefore, human consumption of untreated surface water was included in the assessment of risk for the farmer, fisher, and resident scenarios. However, the inclusion of modeled, untreated surface water concentrations as drinking water in the MPRA is extremely conservative because the surface water used for public supply is treated prior to being used by the public. According to information available from the New River Valley Regional Water Authority, the water sourced from the New River is treated via several processes, including coagulation, flocculation, chlorination, sedimentation, and filtration. Following disinfection, a small amount of ammonia is added to the disinfected water to react with the chlorine to form chloramines to provide a long-lasting disinfectant in the water distribution system. These treatment processes aid in disinfecting the water supply and assist in removing both inorganic and organic compounds.

The drinking water intake rates utilized in the assessment were based upon recommendations provided in Tables 3-15 and 3-33 of USEPA's Exposure Factor's Handbook (USEPA, 2011). Drinking water was included as an exposure pathway in each of the general exposure scenarios.

5.3.5 Skin Absorption Rates

Dermal absorption of COPCs was included in the risk assessment based on requests received by VDEQ, despite the recommendations in the HHRAP to exclude dermal exposure due to the relatively low risks typically resulting from it relative to other exposure scenarios. For assessment of dermal exposure, two receptor-specific factors must be established: the adherence factor, which is provided in units of mg COPC per square centimeter of skin (mg/cm^2) per event, and the skin surface area, which provided in terms of square meters (m^2). For adult receptors, a skin surface area of 2.5 m^2 was used, and for children receptors, a skin surface area of 0.78 m^2 was utilized. Adherence rates were set at 0.07 mg/cm^2 for adults and 0.20 mg/cm^2 for children, based on recommendations from USEPA's Exposure Factor's Handbook (USEPA, 2011).

Another factor used in the dermal calculations is the absorption factor, or ABS. The ABS is a chemical-specific value that accounts for desorption of the chemical from the soil matrix and absorption of the chemical across the skin. Per the methodology used in determining dermal exposure, four criteria are used for determining the ABS fraction:

- If the compound is inorganic, an ABS fraction of 0.01 is assigned;
- If the compound is semivolatile, an ABS fraction of 0.1 is assigned;
- If the compound is volatile but has a vapor pressure lower than benzene, an ABS fraction of 0.03 is assigned;
- If the compound is volatile but has a vapor pressure equal to or greater than benzene, an ABS fraction of 0.005 is assigned.

The dermal absorption factor applied to each COPC based on the above criteria is specified in Table A-9 of Appendix A.

5.4 Exposure Frequency and Duration

Exposure duration is the length of time (in years) that a receptor is exposed via a specific exposure pathway. Exposure frequency is the number of days in each year that the receptor is assumed to be exposed. Table 5-2 provides the exposure frequency and duration for each receptor in the MPRA.

TABLE 5-2
EXPOSURE FREQUENCY AND DURATION FOR TARGETED HUMAN HEALTH RECEPTORS

RECEPTOR	EXPOSURE FREQUENCY [1]	EXPOSURE DURATION [2]
Farmer	Adult: 350 days/year for 40 years Child: 350 days/year for 6 years	24 hours/day
Fisher	Adult: 350 days/year for 20 years Child: 350 days/year for 6 years	24 hours/day
Resident	Adult: 350 days/year for 20 years Child: 350 days/year for 6 years	24 hours/day
Daycare centers	Adult: 350 days/year for 25 years Child: 350 days/year for 6 years	8 hours/day
Elementary schools	Adult: 180 days/year for 25 years Child: 180 days/year for 5 years	8 hours/day
Nursing home	350 days/year for 3 years	24 hours/day
Hospital	7 days/year for 1 year	24 hours/day
Acute risk	1 day per year	1 hour/day

1 Exposure frequency for each receptor based on the HHRAP (USEPA, 2005), with the exception of the exposure duration for the resident and the fisher. At VDEQ's request, the exposure frequency for these two scenarios was based on the Exposure Factor's Handbook (USEPA, 2011).

5.5 AVERAGING TIME

Averaging time represents the time over which exposure to the COPCs is averaged. For non-carcinogenic COPCs, an averaging time of the exposure duration multiplied by 365 days per year was used. For carcinogenic COPCs, the averaging time used was 25,550 days, based on a lifetime exposure of 70 years. Note that this is the most conservative of the three possible exposure situations discussed in the HHRAP.

5.6 BODY WEIGHT

The body weight values used in the exposure calculations affect the daily intake for a given exposure pathway, as the intake is expressed as dose per body weight. The lesser the weight of the receptor, the greater the likely intake for that receptor. For all adult receptors, this MPRA used a body weight of 80 kilograms, based on Table 8-1 of USEPA's Exposure Factor's Handbook (USEPA, 2011). For child receptors, a body weight of 15 kilograms was used for the general receptors and the hospital and daycare scenarios; a body weight of 27 kilograms was used for the elementary school scenario as elementary school children are aged from 6 to 10 and all other children are aged 1 to 6 years old. Each of these body weights are also based on Table 8-1 of USEPA's Exposure Factor's Handbook (USEPA, 2011) at the request of VDEQ.

6.0 HUMAN HEALTH RISK ASSESSMENT RESULTS

Characterization of risk and hazard to the selected human health receptors is the final step of the MPRA process. Using the calculated media concentrations and COPC toxicity values, risk and hazard resulting from the intake of COPCs via each potential pathway are determined. Once complete, these individual risk and hazard estimates are summed to determine the total theoretical risk and hazard predicted for each selected receptor. This section provides a discussion on the results of the human health analysis. Details on the uncertainties associated with this assessment are provided in Section 7 of this report.

6.1 SCOPE AND METHODOLOGY

As discussed in previous sections, the MPRA was conducted to evaluate the potential risk and hazard to members of the population resulting from exposure to COPCs emitted from the RFAAP EWIs. The following individual human exposures were evaluated:

- Risk and hazard to residents living at the maximum impacted offsite location(s) that could allow a domicile to be established. This could include any forested area, agricultural area, or urban area within the assessment area.
- Risk and hazard to subsistence fishers and their children residing at the maximum impacted offsite location(s) that could allow a domicile to be established and fishing in surface waterbodies with the highest modeled fish tissue concentrations in the assessment area.
- Risk and hazard to subsistence farmers and their children residing at the maximum impacted offsite location(s) of agricultural land use and subsisting off of homegrown produce and animal products grown and raised at this location.
- Polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDD/PCDF) exposure to a breast-feeding infant being fed by mothers in each of the three general exposure scenarios (subsistence farmer, subsistence fisher, and resident);
- Lead exposure to receptors in each of the three general exposure scenarios (subsistence farmer, subsistence fisher, and resident);
- Acute hazard to a generic human receptor located at the offsite location with the highest hourly air concentrations;
- Risk and hazard to an elementary school worker and student present at the elementary school(s) with the highest modeled air concentrations and deposition rates;
- Risk and hazard to a daycare worker and child present at the day care center(s) with the highest modeled air concentrations and deposition rates;
- Risk and hazard to a nursing home resident living at the nursing home(s) with the highest modeled air concentrations and deposition rates; and,
- Risk and hazard to adult and child hospital patients at the hospital(s) with the highest modeled air concentrations and deposition rates.

An explanation of the methodology used for each assessment is provided below. Copies of the risk and hazard results for each of these exposure scenarios are provided in Appendix C. The tables in Appendix C are organized as follows:

- Tables C-1.1 through C-1.7 present the COPC intake determined for each exposure scenario with exposure via indirect pathways.
- Tables C-2.1 through C-2.10 present the risk and hazard calculated for each pathway for each exposure scenario.
- Tables C-3.1 through C-3.10 present the risk and hazard calculated for each COPC across all pathways for each exposure scenario.
- Tables C-4.1 through C-4.5 present the acute risk results for each exposure pathway that included an acute risk assessment.
- Tables C-5.1 and C-5.2 present the ALM results for each receptor at Locations A and B, respectively.
- Tables C-6.1 through C-6.6 present the IEUBK results for each of the general exposure scenarios.
- Tables C-7.1 through C-7.10 provide an overall summary of the total risk and hazard calculated for each exposure scenario.

6.1.1 Chronic Risk

Chronic risk was determined by multiplying the appropriate CSF by the site-specific exposure dose using the equations defined in the HHRAP (USEPA, 2005). Chemical-specific risks that are the result of the same exposure route are summed to contributed to the pathway incremental risk; if multiple pathways exist in an exposure scenario, appropriate pathway risks are summed, creating the total incremental carcinogenic risk for a specific receptor population. For this assessment, VDEQ set the following targets:

- The target individual risk from any one chemical in a given exposure scenario was set at $1x10^{-6}$;
- The target cumulative risk from all chemicals in any given exposure scenario was set at $1x10^{-4}$.

6.1.2 Chronic Hazard

Chronic, non-carcinogenic hazard for each receptor was determined by dividing the estimated exposure dose by appropriate dose-response values, such as RfDs derived by the USEPA, using the equations defined in Appendix B of HHRAP (USEPA, 2005). The resulting ratio is referred to as the "chemical-specific risk ratio" or hazard quotient (HQ). HQs for individual COPCs are summed to calculate the hazard index (HI) for a pathway. If multiple pathways exist in an exposure scenario, appropriate pathway HIs are added together to calculate a total HI. For this assessment, VDEQ set the following targets:

- The target level HQ for any individual non-carcinogen was set at 0.25, irrespective of target organ;
- The target HI for all non-carcinogens was set at 1.0, irrespective of target organ.

6.1.3 Infant Exposure To Dioxins and Furans in Breast Milk

For each of the general receptors (resident, fisher, and farmer), the effects of infant exposure to PCDD/PCDF through breast milk were also examined. An average daily dose to both the mother and infant was determined based on the mother's intake of PCDD/PCDF in each generic exposure scenario. The ADD calculated for the infant ($ADD_{i/m}$) was compared to a USEPA-estimated ADD for an infant who is exposed to PCDD/PCDF through the ingestion of breast milk from a mother receiving an average background PCDD/PCDF exposure, rather than the exposure due to facility emissions. This USEPA calculated baseline, or threshold value is equal to 60 picograms per kilogram-body weight per day (pg/kg-BW/day).

6.1.4 Lead Exposure

Due to the lack of toxicity parameters (CSFs and RfDs) for chronic lead exposure, USEPA developed the Integrated Exposure Uptake Biokinetic (IEUBK) model for Lead in Children and the Adult Lead Exposure Model (ALM) for worker exposure to lead. These models were used to calculate predicted lead concentrations in the blood of each of the general receptors. The target threshold for this assessment was a blood lead level of 5 micrograms per deciliter (µg/dL) for at least 95 percent of the receptors. For the ALM analysis, the baseline lead level (BLL) was set at 0.967 µg/dL based upon the 2013-2014 National Report on Human Exposure to Environmental Chemicals (NRHEEC), as reported by the Centers for Disease Control (CDC) in the Fourth National Report on Human Exposure to Environmental Chemicals in 2017 (CDC, 2017).

6.1.5 Acute Exposure

In addition to chronic risks, those risks resulting from acute exposure via the inhalation of EWI emissions were also evaluated for a generic acute receptor and each of the special subpopulations. An acute hazard quotient (AHQ) was calculated for each COPC by dividing the hourly air concentration at the assessed location by the AIEC for that COPC. AIECs were determined from NOAA's PACs, which is a hierarchy-based system of the three common public exposure guideline systems: AEGLs, ERPGs, and TEELs, with preference in the hierarchy being assigned in the order listed. At the request of VDEQ, the initial target AHQ for any individual non-carcinogen, irrespective of target organ, was set at 0.25.

6.1.6 Chronic Results for General Receptors

For each of the general receptors, the chronic risk and hazard resulting from long-term, day-to-day exposure to the EWI emissions was calculated at each of the maximum impacted locations defined in Section 4. In addition, infant exposure to PCDD/PCDF in mother's breast milk, and lead exposure to both adults and children were assessed for each of the general receptors. As discussed previously, two different locations were evaluated. The results of each of these assessments are summarized below.

6.1.7 Resident

The maximum exposure locations for each of the resident scenarios were located west-northwest of the EWIs across the New River on existing farmland. Specific exposure criteria utilized for the chronic risk and hazard assessment for the resident were provided in Section 5. In summary, the resident was assumed to reside at the location for 20 years and be present at that location 24 hours per day, 350 days per year. The resident is exposed to emissions via direct inhalation, incidental soil ingestion, dermal exposure to soil, the consumption of homegrown produce, and the ingestion of surface water supplied drinking water. The results of the resident assessment for each location are summarized in Table 6-1. Individual pathway risks, which had no set risk targets, and the chemical-specific risks for each constituent are provided in Appendix C. The following tables pertain to the resident HHRA evaluations:

- Tables C-1.1 and C-1.2 present the COPC intake determined for the resident receptors at Locations A and B, respectively.
- Tables C-2.1 and C-2.2 present the risk and hazard calculated for each pathway of exposure for the resident receptors at Locations A and B, respectively.
- Tables C-3.1 and C-3.2 present the risk and hazard calculated for each COPC across all pathways of the resident exposure scenario at Locations A and B, respectively.
- Tables C-5.1 and C-5.2 provide copies of the ALM results for the residents at Location A and Location B, respectively.
- Tables C-6.1 and C-6.2 provide copies of the IEUBK results for the residents at Location A and Location B, respectively.
- Tables C-7.1 and C-7.2 provide an overall summary of the total risk and hazard calculated for the resident exposure scenario at Locations A and B, respectively.

TABLE 6-1
SUMMARY OF RISK AND HAZARD TO THE RESIDENT RECEPTORS

RESULTS	LOCATION A: 539,200E, 4,117,400N		LOCATION B: 539,300E, 4,117,400N	
	ADULT	CHILD	ADULT	CHILD
Chronic cancer risk (total)	1.86×10^{-7}	5.60×10^{-8}	1.81×10^{-7}	5.44×10^{-8}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds			
Chronic hazard index	0.00059	0.00085	0.00057	0.00083
PCDD/PCDF ADD [1]	4.3×10^{-6}	1.2×10^{-4}	4.3×10^{-6}	1.3×10^{-4}
Lead (ALM) [2]	1.0	2.3	1.0	2.3
Lead (IEUBK) [2]	---	0.6 – 0.3	---	0.6 – 0.3

1 ADD for PCDD/PCDF calculated for both the mother and the breast-feeding infant. Values presented are in units of pg/kg BW-day. Each ADD is compared to an upper threshold of 60 pg/kg BW-day.

2 ALM model used to calculate adult and fetal blood concentrations. BLL for ALM study set based on 2013-2014 data from the CDC (CDC, 2017). IEUBK used to calculate child lead exposure. All exposures are presented in µg/dL of blood and are calculated based on the soil lead concentration predicted in non-tilled soil at the specified receptor. IEUBK results represent the range reported for children from age 6 months to 7 years.

As shown in the table, the total chronic cancer risk and hazard index and individual chemical assessments for the modeled residential scenarios were below the targets established by VDEQ for this HHRA. Even at the unrealistic operating scenario of simultaneous unit operation 365 days per year, none of the established targets are exceeded for the residential receptors at any of the maximum impacted locations. Therefore, RFAAP does not believe any risk-based limits are required to control exposure to these receptors.

6.1.8 Fisher

The maximum exposure locations for each of the fisher scenarios were located west-northwest of the EWIs across the New River on existing farmland. The waterbodies with the highest COPC fish tissue concentrations were Lick Run and the New River. Specific exposure criteria utilized for the chronic risk and hazard assessment for the fisher were provided in Section 5. In summary, the fisher was assumed to reside at the location for 20 years and be present at that location 24 hours per day, 350 days per year. The fisher is exposed to emissions via direct inhalation, incidental soil ingestion, dermal exposure to soil, the consumption of homegrown produce and locally caught fish, and the ingestion of surface water supplied drinking water. Individual pathway risks, which had no set risk targets, and the chemical-specific risks for each constituent are provided in Appendix C. The following tables are specific to the fisher HHRA evaluations:

- Tables C-1.3 and C-1.4 present the COPC intake determined for the fisher receptors at Locations A and B, respectively.
- Tables C-2.3 and C-2.4 present the risk and hazard calculated for each pathway of exposure for the fisher receptors at Locations A and B, respectively.
- Tables C-3.3 and C-3.4 present the risk and hazard calculated for each COPC across all pathways of the fisher exposure scenario at Locations A and B, respectively.
- Tables C-5.1 and C-5.2 provide copies of the ALM results for the fishers at both locations.
- Tables C-6.3 and C-6.4 provide copies of the IEUBK results for the fishers at Location A and Location B, respectively.
- Tables C-7.3 and C-7.4 provide an overall summary of the total risk and hazard calculated for the fisher exposure scenario at Locations A and B, respectively.

Table 6-2
Summary of Risk and Hazard to the Fisher Receptors

Results	Location A: 539,200E, 4,117,400N		Location B: 539,300E, 4,117,400N	
	Adult	Child	Adult	Child
Chronic cancer risk (total)	1.88×10^{-7}	5.71×10^{-8}	1.83×10^{-7}	5.55×10^{-8}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds			
Chronic hazard index	0.0012	0.0022	0.0011	0.0021
PCDD/PCDF ADD [1]	3.3×10^{-5}	9.6×10^{-4}	3.3×10^{-5}	9.6×10^{-4}
Lead (ALM) [2]	1.0	2.3	1.0	2.3
Lead (IEUBK) [2]	---	0.5 – 0.3	---	0.5 – 0.3

1 ADD for PCDD/PCDF calculated for both the mother and the breast-feeding infant. Values presented are in units of pg/kg BW-day. Each ADD is compared to an upper threshold of 60 pg/kg BW-day.

2 ALM model used to calculate adult and fetal blood concentrations. BLL for ALM study set based on 2013-2014 data from the CDC (CDC, 2017). IEUBK used to calculate child lead exposure. All exposures are presented in µg/dL of blood and are calculated based on the soil lead concentration predicted in non-tilled soil at the specified receptor.

As shown in the table, the total chronic cancer risk and hazard index and individual chemical assessments for the modeled fisher scenarios were below the targets established by VDEQ for this HHRA. Even at the unrealistic operating scenario of simultaneous unit operation 365 days per year, none of the established targets are exceeded for the residential receptors at any of the maximum impacted locations. Therefore, RFAAP does not believe any risk-based limits are required to control exposure to these receptors.

6.1.9 Farmer

The maximum exposure locations for each of the farmer scenarios were located west-northwest of the EWIs across the New River on existing farmland. Specific exposure criteria utilized for the chronic risk and hazard assessment for the farmer were provided in Section 5. In summary, the farmer was assumed to reside at the location for 40 years and be present at that location 24 hours per day, 350 days per year. The farmer is exposed to emissions via direct inhalation, incidental soil ingestion, dermal exposure to soil, the consumption of homegrown produce and animal products, and the ingestion of surface water supplied drinking water. The results of the farmer assessment for each location are summarized in Table 6-3. Individual pathway risks, which had no set risk targets, and the chemical-specific risks for each constituent are provided in Appendix C. The following tables are specific to the farmer HHRA evaluations:

- Tables C-1.5 and C-1.6 present the COPC intake determined for the farmer receptors at Locations A and B, respectively.
- Tables C-2.5 and C-2.6 present the risk and hazard calculated for each pathway of exposure for the farmer receptors at Locations A and B, respectively.
- Tables C-3.5 and C-3.6 present the risk and hazard calculated for each COPC across all pathways of the farmer exposure scenario at Locations A and B, respectively.
- Tables C-5.1 and C-5.2 provide copies of the ALM results for the fishers at Location A and Location B, respectively.
- Tables C-6.5 and C-6.6 provide copies of the IEUBK results for the fishers at Location A and Location B, respectively.
- Tables C-7.5 and C-7.6 provide an overall summary of the total risk and hazard calculated for the farmer exposure scenario at Locations A and B, respectively.

TABLE 6-3
SUMMARY OF RISK AND HAZARD TO THE FARMER RECEPTORS

RESULTS	LOCATION A: 539,200E, 4,117,400N		LOCATION B: 539,300E, 4,117,400N	
	ADULT	CHILD	ADULT	CHILD
Chronic cancer risk (total)	4.68×10^{-7}	7.72×10^{-8}	4.56×10^{-7}	7.52×10^{-8}
Chronic cancer risk (individual chemicals)	No chemical-specific risks over VDEQ thresholds			
Chronic hazard index	0.0017	0.0033	0.0016	0.0032
PCDD/PCDF ADD [1]	1.2×10^{-3}	3.5×10^{-2}	1.2×10^{-3}	3.5×10^{-2}
Lead (ALM) [2]	1.0	2.3	1.0	2.3
Lead (IEUBK) [2]	---	0.4 – 0.2	---	0.4 – 0.2

1 ADD for PCDD/PCDF calculated for both the mother and the breast-feeding infant. Values presented are in units of pg/kg BW-day. Each ADD is compared to an upper threshold of 60 pg/kg BW-day.

2 ALM model used to calculate adult and fetal blood concentrations. BLL for ALM study set based on 2013-2014 data from the CDC (CDC, 2017). IEUBK used to calculate child lead exposure. All exposures are presented in µg/dL of blood and are calculated based on the soil lead concentration predicted in non-tilled soil at the specified receptor. IEUBK results represent that range reported for children from age 6 months to 7 years.

As shown in the table, the total chronic cancer risk and hazard index and individual chemical assessments for the modeled farmer scenarios were below the targets established by VDEQ for this HHRA. Even at the unrealistic operating scenario of simultaneous unit operation 365 days per year, none of the established targets are exceeded for the residential receptors at any of the maximum impacted locations. Therefore, RFAAP does not believe any risk-based limits are required to control exposure to these receptors.

6.2 ACUTE EXPOSURE RESULTS

An acute exposure analysis was conducted for the general population exposed to off-site air concentrations of compounds emitted from the EWIs. The exposure compared the modeled hourly air concentrations to the AIEC for each constituent of concern. The acute receptor, who was positioned at Location C, as defined earlier, was assumed to be exposed to EWI emissions one hour a day for one day per year. Additional exposure criteria for the acute analysis were detailed in Section 5. The results of the acute exposure assessment are summarized in Table 6-4. The constituents with the ten highest AHQs are detailed in the table. None of the AHQs exceeded VDEQ-established targets; therefore, RFAAP does not believe any risk-based limits are required to control exposure to these receptors. A complete list of the AHQs for each COPC are provided in Table C-4.1 in Appendix C.

TABLE 6-4
SUMMARY OF ACUTE HAZARD QUOTIENTS

CONSTITUENT	LOCATION C: 539,600E, 4,117,500N		
	CAIR (MG/M^3)	AIEC (MG/M^3)	AHQ
Lead	7.5×10^{-5}	0.15	5.0×10^{-4}
Nickel	7.3×10^{-7}	0.0060	1.2×10^{-4}
Nitroglycerin	4.6×10^{-6}	0.10	4.6×10^{-5}
1,2-Dibromo-3-Chloropropane	1.2×10^{-7}	0.0030	4.0×10^{-5}
Benzoic acid	6.8×10^{-5}	13	5.2×10^{-6}
Copper	1.1×10^{-5}	3.0	3.7×10^{-6}
Phosphorous	7.9×10^{-7}	0.27	2.9×10^{-6}
Aluminum	5.0×10^{-6}	3.0	1.7×10^{-6}
Pentachlorophenol	1.9×10^{-6}	1.5	1.3×10^{-6}
Benzyl alcohol	2.2×10^{-5}	30	7.4×10^{-7}

6.3 CHRONIC AND ACUTE RESULTS FOR SPECIAL SUBPOPULATIONS

In addition to assessing risk for the general receptors, the chronic and acute risk and hazard to special subpopulations within the assessment area was evaluated in the MPRA. As described in Section 4, these assessments were conducted at the elementary schools, day care centers, nursing homes, and hospitals with the highest modeled air concentrations and deposition rates. The results of each of these assessments are summarized below.

6.3.1 ELEMENTARY SCHOOLS

Risk assessment calculations were performed for teachers and students at a theoretical elementary school that represented the worst-case modeling results from all of the elementary schools in the area. Both the teachers and students were assumed to be exposed to emissions 8 hours per day for 180 days per year via the inhalation of emissions and the incidental ingestion of soil. Acute risk to both the students and the teachers was also assessed. A summary of the calculated risk and hazard is provided in Table 6-5. Individual pathway risks, which had no set risk targets, and AHQs for each constituent are provided in Appendix C. Results can be found in the following tables:

- Table C-1.7 presents the calculated COPC intakes for the elementary school teachers and students.
- Table C-2.7 presents the risk and hazard calculated for each pathway in the elementary school exposure scenario.
- Table C-3.7 presents the risk and hazard calculated for each COPC across all pathways in the elementary school exposure scenario.
- Table C-4.2 presents the acute risk results for the elementary school exposure scenario.

- Table C-7.7 provides an overall summary of the total risk and hazard calculated for the teacher and students at the elementary school.

TABLE 6-5
SUMMARY OF RISK AND HAZARD TO ELEMENTARY SCHOOL STUDENTS AND TEACHERS

RESULTS	ELEMENTARY SCHOOL	
	TEACHER	STUDENT
Chronic cancer risk	5.9×10^{-9}	1.2×10^{-9}
Chronic hazard index	0.000010	0.000010
Acute risk	No AHQs above 0.25	

As shown above, none of the VDEQ-established thresholds for either chronic or acute exposure were exceeded in the risk calculations for the elementary school scenario. Therefore, RFAAP does not believe any risk management limits are required to control exposure of students or teachers at any of the area schools.

6.3.2 DAY CARE CENTERS

Risk assessment calculations were performed for teachers and students at a theoretical daycare center that represented the worst-case modeling results from all of the daycare centers in the area. Both the teachers and students were assumed to be exposed to emissions 8 hours per day for 350 days per year via the inhalation of emissions and the incidental ingestion of soil. Acute risk to both the students and the teachers was also assessed. A summary of the calculated risk and hazard is provided in Table 6-6. Individual pathway risks, which had no set risk targets, and AHQs for each constituent are provided in Appendix C. Results can be found in the following tables:

- Table C-1.8 presents the calculated COPC intakes for the daycare teachers and students.
- Table C-2.8 presents the risk and hazard calculated for each pathway in the daycare exposure scenario.
- Table C-3.8 presents the risk and hazard calculated for each COPC across all pathways in the daycare exposure scenario.
- Table C-4.3 presents the acute risk results for the daycare exposure scenario.
- Table C-7.8 provides an overall summary of the total risk and hazard calculated for the teacher and students at the daycare.

TABLE 6-6
SUMMARY OF RISK AND HAZARD TO DAYCARE STUDENTS AND TEACHERS

RESULTS	DAYCARE CENTER	
	TEACHER	STUDENT
Chronic cancer risk	4.3×10^{-9}	1.2×10^{-9}
Chronic hazard index	0.0000074	0.000010
Acute risk	No AHQs above 0.25	

As shown above, none of the VDEQ-established thresholds for either chronic or acute exposure were exceeded in the risk calculations for the daycare exposure scenario. Therefore, RFAAP does not believe any risk management limits are required to control exposure of students or teachers at any of the area daycares.

6.3.3 NURSING HOMES

Risk assessment calculations were performed for elderly residents at a theoretical nursing home that represented the worst-case modeling results from all of the nursing homes in the area. The residents were assumed to be exposed to emissions 24 hours per day for 350 days per year via the inhalation of emissions. Acute risk was also assessed. A summary of the calculated risk and hazard is provided in Table 6-7. Individual pathway risks, which had no set risk targets, and AHQs for each constituent are provided in Appendix C. Results can be found in the following tables:

- Table C-2.9 presents the risk and hazard calculated for each pathway in the nursing home exposure scenario.
- Table C-3.9 presents the risk and hazard calculated for each COPC across all pathways in the nursing home exposure scenario.
- Table C-4.4 presents the acute risk results for the nursing home exposure scenario.
- Table C-7.9 provides an overall summary of the total risk and hazard calculated for the nursing home residents.

TABLE 6-7
SUMMARY OF RISK AND HAZARD TO NURSING HOME RESIDENTS

RESULTS	NURSING HOME RESIDENT
Chronic cancer risk	9.4×10^{-10}
Chronic hazard index	0.000013
Acute risk	No AHQs above 0.25

As shown above, none of the VDEQ-established thresholds for either chronic or acute exposure were exceeded in the risk calculations for the nursing home exposure scenario. Therefore, RFAAP does not believe any limits are required to control exposure of students or teachers at any of the area nursing homes.

6.3.4 HOSPITALS

Risk assessment calculations were performed for adult and child patients at LewisGale Hospital Montgomery, which was the maximum impacted hospital location. The hospital patients were assumed to be exposed to emissions 24 hours per day for 7 days per year via the inhalation of emissions. Acute risk was also assessed. A summary of the calculated risk and hazard is provided in Table 6-8. Individual pathway risks, which had no set risk targets, and AHQs for each constituent are provided in Appendix C. Results can be found in the following tables:

- Table C-2.10 presents the risk and hazard calculated for each pathway in the hospital exposure scenario.
- Table C-3.10 presents the risk and hazard calculated for each COPC across all pathways in the hospital exposure scenario.
- Table C-4.5 presents the acute risk results for the hospital exposure scenario.
- Table C-7.10 provides an overall summary of the total risk and hazard calculated for the patients.

TABLE 6-8
SUMMARY OF RISK AND HAZARD TO HOSPITAL PATIENTS

RESULTS	HOSPITAL PATIENT	
	ADULT	CHILD
Chronic cancer risk	4.2×10^{-12}	4.2×10^{-12}
Chronic hazard index	1.8×10^{-7}	1.8×10^{-7}
Acute risk	No AHQs above 0.25	

As shown above, none of the VDEQ-established thresholds for either chronic or acute exposure were exceeded in the risk calculations for the hospital exposure scenario. Therefore, RFAAP does not believe any risk management limits are required to control exposure of patients at the area hospitals.

7.0 ECOLOGICAL EXPOSURE ASSESSMENT

As with the human health assessment, exposure scenarios were developed for the SLERA to estimate the type and magnitude of potential direct and indirect exposure to COPCs in stack emissions associated with the EWIs. The potential release mechanisms for these COPCs are:

- Transport of COPCs in air emissions;
- Transport of COPCs to surface soil and surface water via deposition; and
- Uptake and bioconcentration of COPCs in vegetative and animal tissues from affected soil, surface water, sediment, and air.

Regardless of the application, MPRAs rely on a basic principle that complete exposure pathways from environmental release to human or ecological exposure must exist, or health risks are not present. The primary exposure routes for ecological receptors will vary depending upon the trophic level of the receptor as follows:

- Lower trophic level receptors will be exposed via direct uptake from media, including soil, sediment, and surface water, in the Level 1 community receptor analysis;
- Higher trophic level receptors will experience both direct exposure as well as indirect exposure to COPCs via the ingestion of COPC contaminated organisms or media in the Level 2 analysis.

7.1.1 EXPOSURE ASSESSMENT FOR ECOLOGICAL COMMUNITY EXPOSURE SCENARIO

As discussed previously, the exposure potential for community level receptors was assessed by determining the media (*i.e.,* soil, water, and sediment) concentrations of each COPC and comparing those concentrations to the media-based TRVs detailed earlier. The calculations for determining the media concentrations will be consistent with those described in the 1999 USEPA SLERAP.

For the prairie and forest habitat, the following community level exposure assessments were performed:

- Exposures for terrestrial plants were assessed by comparing COPC soil concentrations to TRVs for terrestrial plants.
- Exposures for insects and other herbivorous invertebrates were assessed by comparing COPC soil concentrations to TRVs for soil invertebrates.

For the freshwater habitat, the following community level exposure assessments were performed:

- Exposures for phytoplankton, aquatic and terrestrial vegetation were assessed by comparing COPC sediment and water concentrations to TRVs for soil, sediment, and freshwater;
- Exposures for benthic invertebrates, insects, and water invertebrates were assessed by comparing COPC sediment and water concentrations to TRVs for soil, sediment, and freshwater; and,
- Exposures for fish were assessed by comparing COPC water concentrations to TRVs for freshwater.

7.1.2 Exposure Assessment for Ecological Food Web Exposure Scenarios

The exposure assessment for the food web receptors considered exposure through the ingestion of contaminated food items and media. Exposures carried through the food chain, taking into account each receptor's trophic level and ingestion rates for the contaminated plants and animals that it ingests. The higher the trophic level, the more complex the assessment.

The daily dose for each measurement receptor was determined via Equation 5-1 in the USEPA's SLERAP guidance and were determined from the following:

- Receptor media, plant, and animal ingestion rates for each plant and animal that it consumes in the food chain pathway;
- COPC concentrations in the ingested media and in each of the ingested plants and animals;
- The proportion of each food item that is contaminated and the fraction of the receptor's diet that consists of that food item; and
- Proportion of ingested media that is contaminated.

The food webs that drive each of these daily dose calculations were presented in Section 4. The sections that follow provide further information on the data that that was used in the exposure assessment and the calculations that were performed. Detailed tables presenting all of the calculation inputs and dose-related media and animal concentrations are provided in Appendix D and Appendix E. The following tables are provided:

- Tables D-1.1 and D-1.2 provide the body weight and ingestion rates utilized for each ecological receptor in the prairie/forest food web and the freshwater food web, respectively.
- Table D-2 presents the constants used in the SLERA, including those used in the media and food-item concentration equations, as well as the distribution of food items within each ecological receptor's diet.
- Table D-3 presents constituent specific data used in the SLERA, including physical and chemical properties, as well as TRVs for each of the class-specific guilds and environmental media.
- Table D-4 presents the food-chain multipliers used for each trophic level in the food web exposure scenarios.
- Table E-1 presents the COPC soil loss constants calculated for the SLERA.
- Table E-2 presents the calculated concentrations of each COPC in the evaluated waterbodies.
- Table E-3 presents the calculated concentrations of each COPC in the soil.
- Table E-4 presents the calculated concentrations of each COPC in terrestrial plants.
- Table E-5 presents the bioconcentration factors and biotransfer factors used to calculate animal concentrations, as well as the resulting concentrations of each COPC in the various ecological food web receptors.

7.1.2.1 Ingestion Rates

Ingestion rates are used in the daily dose equation for each receptor to determine the amount of COPC that is ingested through each food item. All food and water ingestion rates used in this assessment were derived from either USEPA's Wildlife Exposure Factors Handbook (WEFH) (USEPA, 1993) or VDEQ's SLERA for the open burning grounds. Soil ingestion rates were calculated as recommended in the SLERAP guidance from a research study conducted by Beyer in 1994. Table 7-1 summarizes the ingestion rates that were used for each food web receptor. This information is also presented on Tables D-1.1 and D.1.2 in Appendix D.

TABLE 7-1
INGESTION RATES FOR FOOD WEB RECEPTORS

MEASUREMENT RECEPTOR	BODY WEIGHT (GRAMS) [1]	FOOD INGESTION (G/GBW/DAY) [2]		WATER INGESTION (G/GBW/DAY) [3]	SOIL INGESTION (G/GBW/DAY) [4,5]	
Northern bobwhite	190	0.00038	Average adult rate from WEFH	0.00068	0.00	Wild turkey
Canada goose	2,769	1.2E-05	Average adult rate from WEFH	1.9E-05	0.00	Canada goose
Meadow vole	39	0.0077	Average adult rate from WEFH	0.0054	0.018	Meadow vole
American woodcock	218	0.0035	Adult rate from WEFH	0.00046	0.037	American woodcock
Short-tailed shrew	15	0.041	Average adult rate from WEFH	0.015	0.099	White-footed mouse
American robin	80	0.019	Average adult rate from WEFH	0.0018	0.0	American woodcock
Mallard	1,043	0.051	Calculated per WEFH (g/day)	5.6E-05	0.42	Mallard
Raccoon	6,400	0.0084	Calculated per WEFH (g/day)	1.3E-05	0.079	Raccoon
Red Fox	4,130	3.4E-05	WEFH	2.1E-05	9.5E-05	Red Fox
Red-tailed hawk	1,224	9.0E-05	Average adult rate from WEFH	0.00048	0.0	Wild turkey
Great blue heron	2,340	7.7E-05	Adult rate from WEFH	1.92E-05	0.0	Wild turkey

1 Established as the average adult value reported from the WEFH.
2 Presented in terms of wet weight of food ingested per day.
3 As reported by the WEFH.
4 Presented in terms of dry weight of soil ingested per day, assuming a soil bulk density of 1.5 g/cm^3 and a soil moisture content of 0.2 mL/cm^3.
5 Calculated per Beyer, 1994 using the data for the specified species.

7.1.2.2 COPC Concentrations in Food Items

As presented above and as demonstrated in Equation 5-1 of the 1999 EPA SLERA guidance, the concentration of COPCs in each of the measurement receptor's food items must be determined in order to calculate the daily dose to the receptor. These calculations vary slightly depending upon the type of ecological receptor that is being targeted. A brief summary of each method is provided below. Detailed information on each of the calculation methodologies can be found in the 1999 EPA SLERA guidance.

- All media concentrations used in the evaluations, including the waterbody and watershed concentrations, were determined as specified in Section 4.
- For invertebrates, phytoplankton, and rooted aquatic plants, the COPC concentration is a multiple of the respective media concentration. The multiplier used in the calculation is the bioconcentration factor (BCF). BCFs for each media and receptor are provided on Table E-5 of Appendix E.
- For terrestrial plants, the COPC concentration is a summation of the concentrations resulting from direct deposition, air-to-plant transfer, and root uptake. The factors for this equation are calculated as per the HHRAP and the USEPA SLERA guidance.
- For fish, the COPC concentration is a multiple of the dissolved phase water concentration, a BCF for water to fish, and a unitless food chain multiplier (FCM). BCFs for water to fish are provided on Table E-5 of Appendix E.
- For mammals, birds, amphibians, and reptiles, the COPC concentration is a summation of the concentrations provided by each individual food item, plus the concentration provided by soil or sediment ingestion, and the concentration provided by water ingestion. Each of these stages of the summation require a BCF for the media and the receptor and an FCM to account for biomagnification of COPCs within lower trophic level organisms. BCF values for each media are provided on Table E-5 of Appendix E. BCF values for each receptor will be calculated from the biotransfer factor (Ba) provided on Table E-5 and the ingestion rates provided in Table 7-1. The effect of biomagnification on this assessment is discussed in the following section.

The resulting media and food-item concentrations for each of the assessed ecological exposures are provided in Appendix D and Appendix E as follows:

- Constants used in the media concentration calculations are provided in Table D-2.
- Table E-1 presents the COPC soil loss constants calculated for the SLERA.
- Table E-2 presents the calculated concentrations of each COPC in the evaluated waterbodies.
- Table E-3 presents the calculated concentrations of each COPC in the soil.
- Table E-4 presents the calculated concentrations of each COPC in terrestrial plants.
- Table E-5 presents the bioconcentration factors and biotransfer factors used to calculate animal concentrations, as well as the resulting concentrations of each COPC in the various ecological food web receptors.

It is important to note that some of the calculation methodologies and constants used to determine media concentrations in the SLERA are different than those used for the HHRA. Therefore, for proper reference to the SLERA calculations, the reader is referenced to the tables cited above rather than the similar, albeit slightly different, tables provided for the HHRA.

7.1.2.3 Biomagnification

Biomagnification is the process by which a COPC is transferred in a food chain through successive trophic levels. The amount of biomagnification varies with the COPC, just as the bioaccumulation of COPCs varies in the environment. For this SLERA, the FCM ratio approach was used to account for the biomagnifying effect of each COPC, with the ratio of FCMs being referred to as a biomagnification factor (BMF). For a trophic level 2 organism, the BMF is simply equal to the FCM for that COPC; however, for higher trophic level organisms, the BMF is a ratio of the FCM for the evaluated trophic level to the FCM for the trophic level being consumed. The FCMs for each trophic level are presented in Table D-4 of Appendix D.

8.0 ECOLOGICAL RISK ASSESSMENT RESULTS

Once the concentration of COPCs in the respective environmental media and measurement receptors is determined, the TRVs described earlier can be used to assess the relative toxicity of that COPC to the ecological receptors. The actual toxicity assessment used in the SLERA depending on the level of assessment being performed:

- Risk to the community level receptors was determined by comparing the media specific TRV for each COPC in terms of mg COPC/kg media to the calculated media concentration.
- Risk to the food-web receptors was determined by comparing the receptor-specific TRV in terms of an ingested dose to the calculated ingestion of each COPC via each measurement receptor.

These comparisons were then used to complete the risk estimation for the SLERA. Risk characterization for both types of evaluations consisted of calculating ecological screening quotients (ESQ) for each COPC quantitatively evaluated in the SLERA, as well as assessing receptor intake from water ingestion. The ESQ was calculated as follows:

$$ESQ = \frac{EEL}{TRV}$$

where:

- ESQ = Ecological Screening Quotient (dimensionless),
- EEL = Estimated Exposure Level [mass of COPC/mass exposure media (*e.g.*, mg/kg) or mass of COPC ingested/body mass of target receptor-day (*e.g.*, mg/kg-day)], and
- TRV = COPC and receptor-specific TRV [mass of COPC/mass exposure media (*e.g.*, mg/kg) or mass of COPC ingested/body mass of target receptor-day (*e.g.*, mg/kg-day)].

An ESQ less than 1 indicates that there is little or no potential for adverse risk to the corresponding assessment endpoint. While an ESQ equal to or greater than 1 indicates that there is a potential for adverse risk to the corresponding assessment endpoint, it does not, by itself, indicate that COPCs pose an unacceptable risk. In no cases was an ESQ in excess of 1 calculated in this SLERA.

A summary of the cumulative ESQs for each ecological receptor is provided in the sections that follow. Detailed results of the SLERA evaluations are presented in Appendix F of this report. Two tables are provided in Appendix F:

- Table F-1 provides the animal daily dose of each COPC assessed in the SLERA. These daily doses were calculated directly from the intake rates and media concentrations discussed in Section 7.
- Table F-2 provides the resulting ESQs for all of the community and food web receptors.

8.1 Ecological Risk Results for Community Receptors

As discussed in Section 7, risk in the ecological exposure scenario for community receptors included an evaluation of COPC concentrations versus TRVs for four main environmental criteria: soil invertebrates, terrestrial plants, waterbody sediments, and freshwater. The ratio of the COPC media concentration to the TRV, expressed as the ESQ, was summed for each criteria to determine an overall ESQ for each. Table 8-1 summarizes the cumulative ESQ's for the community receptors. ESQ's for individual COPCs for each receptor are provided in Table F-2 of Appendix F. None of the ESQ's exceeded the VDEQ target criteria of 1.0. Therefore, there is no reason to suspect that operation of the EWIs is posing unacceptable levels of risk to the receptors represented in the community analysis.

Table 8-1
Summary of Ecological Screening quotients for Community Receptors

Community Measurement Endpoint	Cumulative Ecological Screening Quotient
Soil invertebrates	4.06×10^{-9}
Terrestrial plants	9.25×10^{-6}
Waterbody sediments	3.84×10^{-5}
Freshwater	2.66×10^{-4}

8.2 Ecological Risk Results for Food Web Receptors

Two different food web exposure scenarios were evaluated, one for receptors located in a combined prairie and forest habitat, and one for receptors located in a freshwater habitat. The results from each of these assessments are presented below.

8.2.1 Prairie-Forest Exposure Scenario

The combined prairie/forest exposure scenario included a food web based SLERA for 8 different ecological receptors, including:

- A Meadow Vole
- A Northern Bobwhite
- A Short-Tailed Shrew
- An American Woodcock
- A Racoon
- An American Robin
- A Red Fox
- A Red-Tailed Hawk

The food web relationships for these receptors was provided in Figure 4-1, and the fraction that each receptor occupied as a portion of the other's food chain was provided in Table D-2 of Appendix D. The final cumulative ESQs for each of the assessed ecological receptors in the prairie-forest habitat are provided in Table 8-2. The ESQs for each individual COPC for each receptor are provided in Table F-2 in Appendix F. None of the ESQ's exceeded the VDEQ target criteria of 1.0. Therefore, there is no reason to suspect that operation of the EWIs is posing unacceptable levels of risk to the receptors represented in the combined prairie-forest exposure scenario.

TABLE 8-2
SUMMARY OF ECOLOGICAL SCREENING QUOTIENTS FOR RECEPTORS IN THE COMBINED PRAIRIE-FOREST EXPOSURE SCENARIO

ECOLOGICAL RECEPTOR	GUILD REPRESENTED	TROPHIC LEVEL REPRESENTED	CUMULATIVE ECOLOGICAL SCREENING QUOTIENT
Meadow vole	Herbivorous mammal	2	8.86×10^{-6}
Northern bobwhite	Herbivorous bird	2	2.26×10^{-7}
Short-tailed shrew	Insectivorous mammal	3	6.37×10^{-4}
American woodcock	Insectivorous bird	3	1.18×10^{-4}
Racoon	Omnivorous mammal	3	8.50×10^{-5}
American robin	Omnivorous bird	3	4.51×10^{-4}
Red fox	Carnivorous mammal	4	7.96×10^{-7}
Red-tailed Hawk	Carnivorous bird	4	1.48×10^{-6}

8.2.2 FRESHWATER EXPOSURE SCENARIO

The freshwater exposure scenario included a food web based SLERA for 8 different ecological receptors, including:

- A Meadow Vole
- A Canada Goose
- A Short-Tailed Shrew
- An American Woodcock
- A Racoon
- A Mallard Duck
- A Red Fox
- A Great Blue Heron

The food web relationships for these receptors was provided in Figure 4-2, and the fraction that each receptor occupied as a portion of the other's food chain was provided in Table D-2 of Appendix D. The final cumulative ESQs for each of the assessed ecological receptors in the freshwater habitat are provided in Table 8-3. The ESQs for each individual COPC for each receptor are provided in Table F-2 in Appendix F. None of the ESQ's exceeded the VDEQ target criteria of 1.0. Therefore, there is no reason to suspect that operation of the EWIs is posing unacceptable levels of risk to the receptors represented in the freshwater exposure scenario.

TABLE 8-3
SUMMARY OF ECOLOGICAL SCREENING QUOTIENTS FOR RECEPTORS IN THE FRESHWATER EXPOSURE SCENARIO

ECOLOGICAL RECEPTOR	GUILD REPRESENTED	TROPHIC LEVEL REPRESENTED	CUMULATIVE ECOLOGICAL SCREENING QUOTIENT
Meadow vole	Herbivorous mammal	2	1.19×10^{-7}
Canada goose	Herbivorous bird	2	1.01×10^{-8}
Short-tailed shrew	Insectivorous mammal	3	1.76×10^{-2}
American woodcock	Insectivorous bird	3	4.13×10^{-4}
Racoon	Omnivorous mammal	3	3.73×10^{-3}
Mallard duck	Omnivorous bird	3	8.51×10^{-5}
Red fox	Carnivorous mammal	4	5.18×10^{-7}
Great blue heron	Carnivorous bird	4	8.54×10^{-9}

9.0 UNCERTAINTY ANALYSIS

The primary goal of the uncertainty analysis is to provide a discussion of the key assumptions used in the risk evaluation that significantly influence the estimate of risk. Uncertainty is inherent in all of the principle components of the risk evaluation. Uncertainty in the MPRA can result from various sources, including:

- The use of conservative assumptions and estimated variable values;
- The application of emission factors established using non-site-specific data during limited testing events or emission factors derived from site-specific data using analytical methods with limits to precision and accuracy;
- The application of air dispersion models with limited accuracy and the use of air models that do not provide wet deposition rates;
- The utilization of theoretical and experimentally based fate and transport equations;
- The use of USEPA TRVs, some of which are derived from animal studies, that have low confidence ratings and high uncertainty factors (UFs); and
- The lack of fate, transport, and toxicity data for every identified COPC, making a complete quantitative characterization of risk from the EWI activities unfeasible.

When combined, these compounded uncertainties result in a conservative estimate of risk. Unfortunately, the degree of conservatism in risk estimates cannot be measured; however, the assumptions combine many conservative factors and are likely to overestimate actual exposure. Furthermore, the methodologies utilized in the MPRA are complex and involve the integration of numerous algorithms that are intended to simulate the release of pollutants into the environment, the fate and transport of those pollutants through environmental media, and the potential of adverse health effects that may result from human exposure to the pollutants. Inherent in all of these evaluations are varying degrees of uncertainty.

Table 9-1 summarizes uncertainties associated with the various steps undertaken to estimate risk. The table includes the potential effect of the uncertainty on the conclusions of the MPRA (overestimation, underestimation, neutral) and the magnitude of the effect, if known.

TABLE 9-1
SUMMARY OF KEY UNCERTAINTIES

UNCERTAINTY	LIKELY EFFECT ON RISK ESTIMATE
Emission factors	The emissions factors established from the site-specific sampling program were based on a series of test runs conducted on using a worst-case waste mixture that involved spiking surrogate streams to the EWI at levels higher than those found during normal day-to-day operation. In addition, this testing was conducted under conditions that were worst-case conditions for pollutant formation and not representative of normal unit operations. Therefore, the emission factors utilized in this assessment overestimate risk.
Emission scenarios	The risk calculations assumed operation of both EWIs simultaneously 365 days per year. In reality, there are multiple periods during the year where both incinerators are shut down for maintenance and, while possible, it is not normal for both units to operate simultaneously. These assumptions regarding the frequency of EWI operation overestimate risk.
Dispersion/Deposition Modeling	The accuracy of the dispersion/deposition modeling output is limited by the ability of the model algorithms to correctly depict atmospheric transport and dispersion of contaminants. It is also limited by the applicability of the meteorological input data to the site; the model uses the most appropriate data that is available. Dispersion/deposition modeling uncertainties may overestimate or underestimate risk.
Calculation of media concentrations	The accuracy of media concentration calculations is limited by the ability of the guidance document equations to correctly estimate media concentrations. Media concentration uncertainties may overestimate or underestimate risk.
Calculation of media concentrations	The media concentrations used in the risk assessment modeling are determined from, among other things, the air modeling concentrations and deposition rates. Therefore, the accuracy of the concentrations is limited by the accuracy of the air modeling programs to accurately predict air concentrations and deposition rates at the modeled locations.
Assumptions regarding exposure duration, frequency and time.	Risk calculations assume that the exposed individuals under the general receptor scenarios are at a single location for 24 hours per day, 350 days per year, for 20 to 40 years. Given the more mobile and working nature of our society, it is unlikely that an individual would reside in the same location for 20 years and/or spend 24 hours per day at that location. This exposure basis, therefore, likely overestimates risk.
Calculation of receptor intake	The accuracy of receptor intake calculations is limited by how closely the intake assumptions fit the actual receptors. The intake rates used and the calculations employed are established to be conservative estimates based on latest guidance but may underestimate or overestimate intake for some receptors.
Calculation of receptor intake	The drinking water source for receptors within the assessment area is treated surface water from the New River. Constituent concentrations assumed for the drinking water are based on calculations from the model. However, the raw water is treated in a manner that effectively removes contaminants from the water. Therefore, intake from this source is overestimated, and risk and hazard resulting from exposure to COPCs in drinking water is most likely overestimated.
Calculation of receptor intake	The calculation of receptor intake for the SLERA receptors was based on information provided in the USEPA's Exposure Wildlife Factor's Handbook. In some cases, ingestion rates for specific receptors were not available and rates from other, similar species were used. (For example, body weight and ingestion data for a wild turkey was used to approximate ingestion rates for the red-tailed hawk). This "extrapolation" of ingestion data from one species to another may result in an over or under estimation of risk for a particulate ecological species.

TABLE 9-1 (CONTINUED)
SUMMARY OF KEY UNCERTAINTIES

UNCERTAINTY	LIKELY EFFECT ON RISK ESTIMATE
Distribution of a receptor's diet	Both the HHRA and the SLERA make assumptions regarding the distribution of food items in each receptor's diet and the portion of each of these food items that are contaminated. In actuality for both humans and ecological receptors, diet proportions can vary due to a combination of socio-economic factors for humans and seasonal and climate variations for both human and ecological receptors. This variation of actual versus assumed diet distribution likely overestimates risk as actual diets are likely more diverse, and, in the case of human health receptors, most likely not supplied in the majority from homegrown sources.
Location of the subsistence farmer	The subsistence farmer is located at the point of highest impact within an area of land that would require clearing to support the farming practice. Therefore, the location of the subsistence farmer likely overestimates risk, as the actual areas readily available to support such farming practice are further from the facility and have lower overall concentrations and deposition rates.
Presence of subsistence farmer	The type of consumption modeled for the subsistence farmer is likely not found within the largely suburban and wooded areas found within the assessment area. While farming does exist within the area, the practice of fully supporting the complete produce and animal product diet is unlikely. This "exaggerated" exposure scenario likely overestimates risk and hazard to the farming population in the area.
Location of subsistence fisher	Consumption of fish contributed significantly to the total incremental risk and hazard for the subsistence fisher. The fish tissue concentrations of COPCs used in the risk calculations were the highest for that constituent and did not necessarily occur in the same body of water. This idea of simultaneous achievability of the maximum tissue concentrations across multiple waterbodies is highly unlikely and overestimates risk to the fisher.
Presence of subsistence fisher	The consumption rates used for the subsistence fisher scenario are very high when compared to typical values for subsistence fishers presented in the Exposure Factors Handbook. In fact, it is more likely that a recreational fisher (freshwater angler) may exist in the assessment area. When compared to typical consumption rates for freshwater anglers in the Exposure Factors Handbook, the consumption rates used in this assessment are greatly exaggerated. These elevated consumption rates overestimate risk and hazard to the subsistence fisher. As part of the assessment, RFAAP reviewed actual fishing trends within the assessment area. These trends speak to the general absence of subsistence-style fishing and can be reviewed online at the HookandBullet and Fisheries references provided herein.
Selection of ecological receptors	The SLERA uses surrogate receptors to evaluate the impact to ecological systems potentially impacted by operation of the EWIs at the RFAAP. While these species are selected based on their prevalence in the ecosystem, they are also largely based on those receptors for which ecological exposure criteria are available. Within each type of guild, the actual ingestion rates, exposure potentials, *etc.,* can vary widely, and the toxicity of COPCs to members of the guild can also vary. Therefore, the accuracy of the SLERA at predicting quantifiable estimates of risk to all members of a given food web is highly uncertain. The actual risk to each member of the ecosystem may be over or underestimated.
Location of ecological receptors	The SLERA assumed that the maximum modeled air concentrations and deposition rates determined with AERMOD were representative of the entire home range of a target ecological receptor. Recognizing that the magnitude of air concentrations and deposition rates varied by several orders across the assessment area, the application of maxima values across a receptor's entire home range likely overestimates risk.

Table 9-1 (continued)
Summary of Key Uncertainties

Uncertainty	Likely Effect on Risk Estimate
Values used for human health cancer slope factors and reference doses.	As requested by VDEQ, toxicity information from the USEPA Region 3 risk screening tables were used in this MPRA. For many constituents, the potential for adverse effects in humans was extrapolated from animal studies, which may overestimate or underestimate risk. Many USEPA-approved toxicity values have low confidence ratings and high uncertainty factors, which may overestimate or underestimate risk.
Values used for ecological TRVs	Toxicity data for the SLERA was obtained from a variety of reputable sources. However, within each source, the data for any one receptor can vary significantly based on the study referenced or the conditions under which the results were obtained. In addition, hierarchies were established with VDEQ guidance on the order in which to reference and utilize the various ecological toxicological data sources. The variation of toxicity values across studies and the differences from one source to the next may result in an over or under estimation of risk.
Values used for ecological TRVs	The ecological TRVs used in this assessment were based on the no observable effect levels (NOAELs) rather than another health matrix, such as a lowest observable adverse effect level (LOAEL). These NOAELS are, as their name implies, levels as which no observable effects occurred in the target species. The delta between the LOAEL and the NOAEL varies by COPC and can, in some cases, be orders of magnitude. Therefore, the use of a NOAEL for a TRV likely overestimates risk.
Calculation of pathway risk and hazard	Total risk for each pathway is calculated by adding risks calculated for each constituent. This is likely to overestimate risk because the COPCs have different target organs and different mechanisms for carcinogenic effects. However, it is possible to underestimate risk if some COPCs have synergistic effects.
Calculation of total risk and hazard	Total risk for each receptor is calculated by adding pathway risks. This is likely to overestimate risk because individual receptors are not likely to simultaneously have reasonable maximum exposure to each pathway.

9.1 Quantitative Uncertainties

Some of the uncertainties with the MPRA process can be quantified better than others. These quantitative uncertainties allow an examination of the risk estimates and the relative scale of those estimates against the modeled versus actual conditions. The sections that follow describe the quantitative uncertainties with the drivers that were identified in this risk estimate.

9.1.1 Risk Assessments

The most impacted exposure scenario for risk evaluations in the HHRA was the subsistence farmer, with a total risk of 4.68×10^{-7} to the adult receptor. The scenario risk was driven by hexavalent chromium in the direct inhalation pathway. Chromium in stack emissions can occur in two primary forms: trivalent chromium and hexavalent chromium. Trivalent chromium is a necessary mineral for humans, while hexavalent chromium is a carcinogen that is dangerous to human health. To be conservative, it was assumed that all chromium existing the stack was hexavalent. In reality, emissions data from this and other incinerators have shown this not to be the case. Therefore, in all of the HHRA exposure scenarios, the risks are likely overstated.

9.1.2 Hazard Assessments

The highest hazard indices were modeled for the farmer at Location A. The driver for this index derives from the produce ingestion pathway and is mainly attributable to emissions of nitroglycerin. Nitroglycerin was not detected in stack emissions during the risk burn. It was included in the risk assessment at the 2020 laboratory detection limit to provide a conservative estimate of emissions of a primary component of RFAAP's waste streams. However, this likely severely overestimates the emission level, as nitroglycerin is very easily destroyed in the incinerator. The autoignition temperature of nitroglycerin is just above 500 degrees Fahrenheit (°F). With a minimum kiln operating temperature of 1,300°F and a minimum afterburner operating temperature of 1,600°F, it is very unlikely that any nitroglycerin will survive the incineration process and transfer downstream and out of the exhaust stack. Therefore, the hazard index represented by nitroglycerin significantly overstates the hazard through this pathway.

9.2 Qualitative Uncertainties

The previous sections focused on the effect that some of the specific items discussed in Table 9-1 would have on hazard and risk estimates. However, for many of the items included in Table 9-1, a broader discussion is warranted. The sections below provide this broader analysis of uncertainty in the MPRA.

9.2.1 Assumptions and Variable Values

In the absence of empirical or site-specific data, assumptions and variable values are developed based on best estimates of exposure or dose-response relationships. To assist in the development of these estimates, USEPA recommends the use of guidelines and standard factors in MPRAs (USEPA, 1989a and 1991). The use of these standard factors is intended to promote consistency among risk evaluations where assumptions must be made. Although the use of standard factors undoubtedly promotes comparability, their usefulness in accurately predicting risk is directly proportional to their applicability to actual site-specific conditions.

This MPRA used many assumptions and variable values based on USEPA and other guidance documents. Different guidance documents often recommend different values for the same variables based on the studies referenced in that particular document. The use of alternate values from those employed in this assessment may result in more or less risk to a given receptor.

Regardless of the source of the variable value, many of these values are considered conservative and are generally more likely to overestimate versus underestimate risk; however, the time needed to develop site-specific factors can be extensive and is not always necessary. In addition, VDEQ expressed a preference for use of these conservative values in place of site-specific values to help provide a cushion in the level of protection that the MPRA asserts. Therefore, the risk estimates provided herein are considered not only protective but conservative based on the default values that were applied.

9.2.2 RISK AND HAZARD FROM CRITERIA POLLUTANTS

Under the Clean Air Act, USEPA establishes air quality standards for six principal air pollutants, referred to as criteria pollutants, to protect public health, including the health of "sensitive" populations such as people with asthma, children, and older adults. These pollutants include: particulate matter, nitrogen dioxide, ozone, sulfur dioxide, carbon monoxide, and lead. While the health effects from lead were assessed in this MPRA, the health effects from the other criteria pollutants were not directly assessed due to a lack of emissions data specific to RFAAP products. A discussion of this omission on the results of the MPRA is provided below for each criteria pollutant.

9.2.2.1 Particulate Matter

Particulate matter from combustion sources is generally characterized as a mixture of non-combustible emission products and metals. Most of this particulate matter falls in the micron to sub-micron category and is generally characterized as PM2.5. The cancer risk and hazard quotient evaluation included in the HHRA already addressed the impact of the PM-metallic fraction on the surrounding community. The other, non-metallic portion of PM is controlled via application of the HWC NESHAP emission standard for PM. This emission limitation represents the maximum achievable control technology (MACT) for hazardous waste incinerators throughout the United States.

While actual PM sizing data is not available from RFAAP's incinerator, total PM emissions data is available due to compliance testing conducted to demonstrate compliance with the HWC NESHAP. PM emission rates during the June 2000 testing were reported at 0.075 lb/hr, or 0.0094 g/sec. Appling this emission factor at the area of highest particle phase air concentration and assuming that all PM measured in emissions was in the form of PM2.5, the annual average PM2.5 air concentration would be 0.016 $\mu g/m^3$.

The PM2.5 NAAQS to ensure protection of public health and the environment. The primary standards are designed to protect public health, including sensitive populations. The secondary standards are designed to protect public welfare, including protection against decrease visibility and damage to animals, crops, and vegetation. The current primary and secondary NAAQS for PM2.5 are 12.0 $\mu g/m^3$ and 15.0 $\mu g/m^3$, respectively. Comparing the NAAQS and the estimated PM2.5 concentrations from the incinerators, it does not appear as if the PM2.5 emissions from the EWI operations pose a threat to human health or the environment. The highest estimated PM2.5 concentration is only 0.13 percent of the primary NAAQS and 0.11 percent of the secondary NAAQS. Furthermore, these concentrations assume operation 365 days per year, which is not realistic. Therefore, the actual PM2.5 concentrations and impact should be even less than this prediction.

9.2.2.2 Nitrogen Dioxide

Nitrogen dioxide, or NO_2, is a reddish brown, highly reactive gas that is formed in the ambient air through the oxidation of nitric oxide (NO). Nitrogen oxides (NOx), the generic term for a group of highly reactive gases that contain nitrogen and oxygen in varying amounts, play a major role in the formation of ozone, PM, haze, and acid rain. NOx are readily produced through thermal treatment of the highly nitrogenated wastes processed at the RFAAP EWIs. However, no recent emissions data on predicted NOx emission levels is available for the EWIs. Therefore, it is not possible to provide a direct quantitative impact of the risk from them in this MPRA. Furthermore, any NOx that was produced would be partially removed by the wet scrubber included in the air pollution control system.

Short-term exposures (e.g., less than 3 hours) to NO_2 may lead to respiratory disorders. Long-term exposures to NO_2 may lead to increased susceptibility to respiratory infection and may cause irreversible impacts on lung tissue. In addition, NOx can react in the air to form ground-level ozone and fine particle pollution, which are also associated with adverse health effects. Based on the air modeling results, the primary impact from these effects would be to the northwest of the EWIs. Being unable to characterize the quantitative risk from this exposure may underestimate risk. However, visual observations of unit emissions do not provide any indication of high NOx levels from the EWIs, as a reddish-brown cloud has not been observed from the EWI exhaust stacks during any normal operations in recent history. As such, it is likely that any impact from exclusion of NO_2 from this risk evaluation is minimal.

9.2.2.3 Ozone

Ozone occurs naturally in the stratosphere above the earth's surface and forms a layer that protects life on earth from the sun's harmful rays. Ozone is also formed at ground level by a chemical reaction of various air pollutants combined with sunlight. The pollutants that contribute to ozone formation are NOx and volatile organic compounds (VOCs). Given the tight control requirements on hydrocarbons from the EWI exhaust stack (an HWC NESHAP limitation of 10 parts per million by volume, corrected to seven percent oxygen), the likelihood of high ozone production from the EWIs is minimal.

9.2.2.4 Sulfur Dioxide

Sulfur dioxide (SO_2) is formed when fuel containing sulfur is burned. Only a small percentage of the wastes processed in the RFAAP EWIs contain sulfur. Therefore, although the SO_2 emissions from the EWI were not quantified as part of the June 2000 risk burn, the overall SO_2 emissions are expected to be minor based on data that is known on the wastes being processed. Likewise, the impact of SO_2 emissions from the EWI on the overall risk and hazard from burning ground emissions is expected to be negligible.

9.2.2.5 Carbon Monoxide

Carbon monoxide is a colorless and odorless gas, formed when carbon in fuel is not burned completely. At the EWI, CO is formed through the incomplete combustion of carbon-based elements in the waste, such as hydrocarbons and dunnage items used in skid burns. However, the HWC NESHAP limits CO from the incinerators to no more than 100 ppmv, corrective to seven percent oxygen. The EWIs are equipped with a continuous emissions monitor (CEMS) that indicate that unit emissions are normally only a small fraction of this emission limitation. Therefore, the emissions of CO from the EWIs is not suspected to cause any significant human health or ecological impact.

9.2.3 Air Modeling Methods

Although air dispersion modeling is a valuable tool for estimating concentration and deposition impacts, it has many limitations. The accuracy of the model is limited by the ability of the model algorithms to depict atmospheric transport and dispersion of contaminants, and the accuracy and validity of the input data. For instance, most refined models require input of representative meteorological data from a single measurement station, while, in reality, a release will encounter highly variable meteorological conditions that are constantly changing as it moves downwind. These factors, coupled with variations in model algorithms, effect the predicted movement of COPCs through the atmosphere and to ground. These various and mitigating factors can directly impact the determination of media concentrations of each of the selected COPCs. Major uncertainties in all air modeling efforts, as explained in the USEPA's HHRAP, include the determination of atmospheric deposition rates and the setting of deposition-related input variables, and the long-range transport of pollutants into and out of the study area (USEPA, 2005).

9.2.4 Fate and Transport Equations

The HHRAP and the SLERAP provide numerous equations to determine the fate and transport of pollutants through environmental media, and the impact that those pollutants have on the exposed population. These equations were developed from what USEPA determined to be the best-available information at the time the two guidance documents were published. Unfortunately, these equations are based on either theoretical assumptions, experimentally determined relationships, or undetermined sources. Therefore, each equation employed has uncertainty associated with it. As with the other sources of uncertainty, when the uncertainties associated with each equation are compounded, the resultant media concentrations, intake rates, and risk determinations are highly conservative.

For the equations that were used for the fate and transport assessment, USEPA identified the uncertainties associated with each equation to the best extent possible in the Appendices to the HHRAP. In general, the uncertainties that are explained provide opportunities for both overestimation and underestimation of risk.

9.2.5 Toxicity Values

The determination of risk and hazard associated with a given pollutant is based largely on toxicity values recommended by USEPA. The HHRA used values from USEPA Region 3's RSL database. Even though the database values are reviewed and updated frequently by various USEPA work groups, each value has varying degrees of confidence and uncertainty associated with it. USEPA ranks the confidence level of the source study, the study database, and the derived risk factor on a three-point scale: low, medium and high. Using values with low confidence ratings increases the uncertainty in the MPRA. Also, each risk factor has an associated UF that allows for interspecies extrapolation, sensitive population protection, database deficiencies, and subchronic to chronic extrapolation. These UFs, which work as multipliers, can range from low (*e.g.* 10) to high (*e.g.* 3,000).

9.2.6 UNQUANTIFIED RISK AND HAZARD

Not all of the constituents identified in the EWI emissions during the June 2000 risk burn were included in the risk and hazard analyses. Some of these constituents lacked reliable fate and transport data, while others did not have sufficient toxicity data available. It is possible that the omission of these compounds from the quantitative evaluation may underestimate the total risk and hazard to studied receptors. However, USEPA gathered fate, transport, and toxicological data on compounds that they feel pose the most threat to human health and the environment through the establishment of lists of criteria pollutants and hazardous air pollutants in the Clean Air Act, priority pollutants in the Clean Water Act, principle organic hazardous constituents under the Resource Conservation and Recovery Program, and other toxic chemicals under the Toxic Substances Control Act. Furthermore, USEPA specifically developed the Integrated Risk Information System (IRIS) to fulfill their mission of protecting human health and the environment. As explained by USEPA on the IRIS website, "EPA's IRIS program supports this mission by identifying and characterizing the health hazards of chemicals found in the environment." USEPA has made a considerable effort to characterize those compounds that pose the most harm to human health and the environment and to develop the data necessary to assess the risks they pose.

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Appendix A: INPUT DATA FOR THE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

This Appendix provides copies of the tables generated as part of the risk assessment calculations. These tables were generated from a spreadsheet-based application. In some cases, the tables contain formatting or numerical references that are used in the calculations themselves. While not integral to the presentation of the results, these references cannot be removed without compromising the spreadsheet-based application. The reader is referred to the main portion of this report for explanation of the data represented in the tables, including acronym definitions, data sources, *etc.* For calculation of any field provided in the tables, please reference the associated HHRAP or SLERAP equation cited at the top of each field's column.

LIST OF TABLES FOR APPENDIX A

Table Title **No. of Pgs**

Appendix B: ENVIRONMENTAL MEDIA CONCENTRATIONS FOR THE HUMAN HEALTH RISK ASSESSMENT

This Appendix provides copies of the tables generated as part of the risk assessment calculations. These tables were generated from a spreadsheet-based application. In some cases, the tables contain formatting or numerical references that are used in the calculations themselves. While not integral to the presentation of the results, these references cannot be removed without compromising the spreadsheet-based application. The reader is referred to the main portion of this report for explanation of the data represented in the tables, including acronym definitions, data sources, *etc.* For calculation of any field provided in the tables, please reference the associated HHRAP equation cited at the top of each field's column. In cases where field values are shown as "#NUM", the value for that parameter is not applicable to the receptor or scenario being evaluated. For example, resident receptors are only exposed to non-tilled soil; therefore, tilled soil values and values calculated from those may be presented as "#NUM".

LIST OF TABLES FOR APPENDIX B

Table Title **No. of Pgs**

Appendix C: HUMAN HEALTH RISK ASSESSMENT RESULTS

This Appendix provides copies of the tables generated as part of the risk assessment calculations. These tables were generated from a spreadsheet-based application. In some cases, the tables contain formatting or numerical references that are used in the calculations themselves. While not integral to the presentation of the results, these references cannot be removed without compromising the spreadsheet-based application. The reader is referred to the main portion of this report for explanation of the data represented in the tables, including acronym definitions, data sources, *etc.* For calculation of any field provided in the tables, please reference the associated HHRAP equation cited at the top of each field's column.

LIST OF TABLES FOR APPENDIX C

Appendix D: ADDITIONAL INPUT DATA FOR THE ECOLOGICAL RISK ASSESSMENT

This Appendix provides copies of the tables generated as part of the risk assessment calculations. These tables were generated from a spreadsheet-based application. In some cases, the tables contain formatting or numerical references that are used in the calculations themselves. While not integral to the presentation of the results, these references cannot be removed without compromising the spreadsheet-based application. The reader is referred to the main portion of this report for explanation of the data represented in the tables, including acronym definitions, data sources, *etc.* For calculation of any field provided in the tables, please reference the associated SLERAP equation cited at the top of each field's column.

LIST OF TABLES FOR APPENDIX D

Table Title **No. of Pgs**

Appendix E: ENVIRONMENTAL MEDIA CONCENTRATIONS FOR THE ECOLOGICAL RISK ASSESSMENT

This Appendix provides copies of the tables generated as part of the risk assessment calculations. These tables were generated from a spreadsheet-based application. In some cases, the tables contain formatting or numerical references that are used in the calculations themselves. While not integral to the presentation of the results, these references cannot be removed without compromising the spreadsheet-based application. The reader is referred to the main portion of this report for explanation of the data represented in the tables, including acronym definitions, data sources, *etc.* For calculation of any field provided in the tables, please reference the associated SLERAP equation cited at the top of each field's column.

LIST OF TABLES FOR APPENDIX E

Appendix F: ECOLOGICAL RISK ASSESSMENT RESULTS

This Appendix provides copies of the tables generated as part of the risk assessment calculations. These tables were generated from a spreadsheet-based application. In some cases, the tables contain formatting or numerical references that are used in the calculations themselves. While not integral to the presentation of the results, these references cannot be removed without compromising the spreadsheet-based application. The reader is referred to the main portion of this report for explanation of the data represented in the tables, including acronym definitions, data sources, *etc.* For calculation of any field provided in the tables, please reference the associated SLERAP equation cited at the top of each field's column.

LIST OF TABLES FOR APPENDIX F

Table Title **No. of Pgs**